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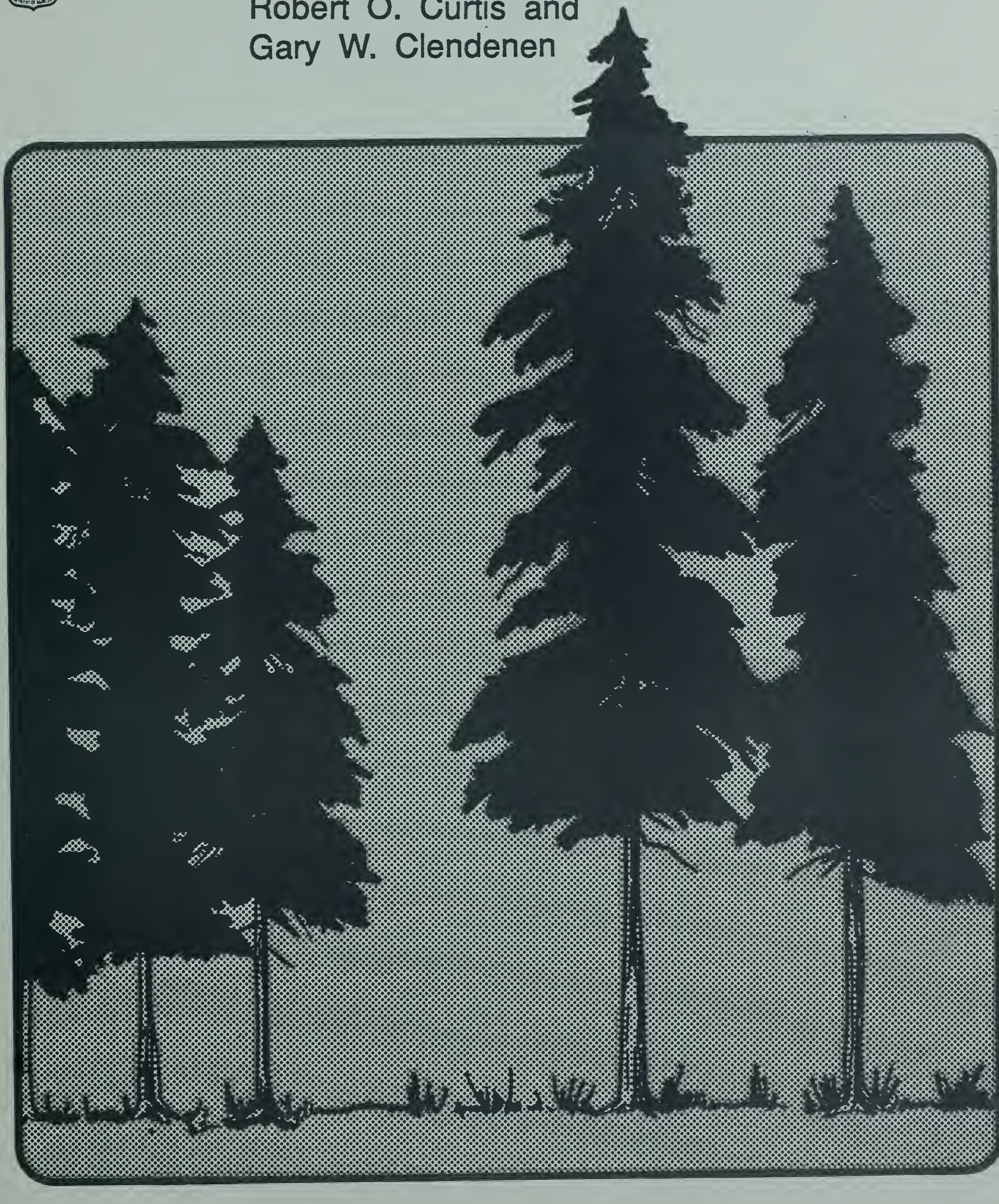
# Levels-of-Growing-Stock Cooperative Study in Douglas-Fir: Report No. 12--the Iron Creek Study: 1966-89

Robert O. Curtis and
Gary W. Clendenen



Levels-of-growing-stock study treatment schedule, showing percent of gross basal area increment of control plots to be retained in growing stock

| | Treatment | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Thinning | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | Percent | | | | | | | |
| First | 10 | 10 | 30 | 30 | 50 | 50 | 70 | 70 |
| Second | 10 | 20 | 30 | 40 | 50 | 40 | 70 | 60 |
| Third | 10 | 30 | 30 | 50 | 50 | 30 | 70 | 50 |
| Fourth | 10 | 40 | 30 | 60 | 50 | 20 | 70 | 40 |
| Fifth | 10 | 50 | 30 | 70 | 50 | 10 | 70 | 30 |

## Background

Public and private agencies are cooperating in a study of eight thinning regimes in young Douglas-fir stands. Regimes differ in the amount of basal area allowed to accrue in growing stock at each successive thinning. All regimes start with a common level of growing stock established by a conditioning thinning.

Thinning interval is controlled by height growth of crop trees, and a single type of thinning is prescribed.

Nine study areas, each involving three completely random replications of each thinning regime and an unthinned control, have been established in western Oregon and Washington, U.S.A., and on Vancouver Island, British Columbia, Canada. Site quality of these areas varies from I through IV.

This is a progress report on this cooperative study.

# Levels-of-Growing-Stock Cooperative Study in Douglas-Fir:

# Report No.12—The Iron Creek Study: 1966-89.

Robert O. Curtis, Principal Mensurationist
Gary W. Clendenen, Mensurationist
Pacific Northwest Research Station
Forestry Sciences Laboratory
Olympia, Washington

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## Abstract

**Curtis, Robert O.; Clendenen, Gary W. 1994.** Levels-of-growing-stock cooperative study in Douglas-fir: report no. 12—the Iron Creek study: 1966-89. Res. Pap. PNW-RP-475. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 67 p.

Results of the Iron Creek installation of the levels-of-growing-stock study in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) are summarized. To age 42 (planned completion of the experiment) volume growth in this site II Douglas-fir plantation has been strongly related to level of growing stock, partially offsetting the decrease in volume growth percent expected with increasing growing stock. Basal area growth-growing stock relations were much weaker than those for volume. Marked differences in tree size distributions have resulted from thinning. Periodic annual volume increments are two to three times greater than mean annual increments at age 42; this stand is far from culmination. Results in general are similar to those reported for other installations in the series on medium to good sites.

Keywords: Thinning, growing stock, growth and yield, stand density, Douglas-fir, *Pseudotsuga menziesii*, series—Douglas-fir LOGS.

## Summary

Results of the Iron Creek installation of the cooperative levels-of-growing-stock study in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), located in the Randle District of the Gifford Pinchot National Forest in southern Washington, are summarized through age 42 (completion of 60 feet of height growth, comprising the planned course of the experiment).

Estimated site index (50-year base) of this plantation is 126 (mid-site II). Contrary to expectations when the study was established, volume growth has been strongly related to growing stock; basal area growth much less so. There is a substantial tradeoff between increased individual tree size and value and total cubic volume production. Volume growth percentages have been considerably higher than those for basal area growth. At age 42, growth percentages in merchantable cubic volume are not strongly related to growing stock. Different growing stock levels have produced marked differences in tree size distributions and crown dimensions. Periodic annual cubic volume increments are two to three times greater than mean annual increments at age 42; the stand is far from culmination. Results have been generally comparable to those reported from other installations in the study on medium to good sites.

## Other LOGS (Levels-of-Growing-Stock) Reports

**Williamson, Richard L.; Staebler, George R. 1965.** A cooperative level-of-growing-stock study in Douglas-fir. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 12 p.

Describes purpose and scope of a cooperative study investigating the relative merits of eight different thinning regimes. Main features of six study areas installed between 1961 and 1965 in young stands also are summarized.

**Williamson, Richard L.; Staebler, George R. 1971.** Levels-of-growing-stock cooperative study on Douglas-fir: report no. 1—description of study and existing study areas. Res. Pap. PNW-111. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 12 p.

Thinning regimes in young Douglas-fir stands are described. Some characteristics of individual study areas established by cooperating public and private agencies are discussed.

**Bell, John F.; Berg, Alan B. 1972.** Levels-of-growing-stock cooperative study on Douglas-fir: report no. 2—the Hoskins study, 1963-1970. Res. Pap. PNW-130. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 19 p.

A calibration thinning and the first treatment thinning in a 20-year-old Douglas-fir stand at Hoskins, Oregon, are described. Data tabulated for the first 7 years of management show that growth changes in the thinned stands were greater than anticipated.

**Diggle, P.K. 1972.** The levels-of-growing-stock cooperative study in Douglas-fir in British Columbia (report no. 3, cooperative L.O.G.S. study series). Inf. Rep. BC-X-66. Victoria, BC: Canadian Forestry Service, Pacific Forest Research Centre. 46 p.

**Williamson, Richard L. 1976.** Levels-of-growing-stock cooperative study in Douglas-fir: report no. 4—Rocky Brook, Stampede Creek, and Iron Creek. Res. Pap. PNW-210. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 39 p.

The USDA Forest Service maintains three of nine installations in a regional, cooperative study of influences of levels of growing stock (LOGS) on stand growth. The effects of calibration thinnings are described for the three areas. Results of first treatment thinning are described for one area.

**Berg, Alan B.; Bell, John F. 1979.** Levels-of-growing-stock cooperative study on Douglas-fir: report no. 5—the Hoskins study, 1963-1975. Res. Pap. PNW-257. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 29 p.

The study dramatically demonstrates the capability of young Douglas-fir stands to transfer the growth from many trees to few trees. It also indicates that at least some of the treatments have the potential to equal or surpass the gross cubic-foot volume of the controls during the next treatment periods.

**Arnott, J.T.; Beddows, D. 1981.** Levels-of-growing-stock cooperative study in Douglas-fir: report no. 6—Sayward Forest, Shawnigan Lake. Inf. Rep. BC-X-223. Victoria, BC: Canadian Forestry Service, Pacific Forest Research Centre. 54 p.

Data are presented for the first 8 and 6 years at Sayward Forest and Shawnigan Lake, respectively. The effects of the calibration thinnings are described for these two installations on Vancouver Island, British Columbia. Results of the first treatment thinning at Sayward Forest for a 4-year response period also are included.

**Williamson, Richard L.; Curtis, Robert O. 1984.** Levels-of-growing-stock cooperative study in Douglas-fir: report no. 7—preliminary results; Stampede Creek, and some comparisons with Iron Creek and Hoskins. Res. Pap. PNW-323. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 42 p.

Results of the Stampede Creek LOGS study in southwest Oregon are summarized through the first treatment period, and results are compared with two more advanced LOGS studies and are generally similar.

**Curtis, Robert O.; Marshall, David D. 1986.** Levels-of-growing-stock cooperative study in Douglas-fir: report no. 8—the LOGS study: twenty-year results. Res. Pap. PNW-356. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 113 p.

Reviews history and status of LOGS study and provides new analyses of data, primarily from the site II installations. Growth is strongly related to growing stock. Thinning treatments have produced marked differences in volume distribution by tree size. At the fourth treatment period, current annual increment is still about double mean annual increment. Differences among treatments are increasing rapidly. There are considerable differences in productivity among installations, beyond those accounted for by site differences. The LOGS study design is evaluated.

**Curtis, Robert O. 1987.** Levels-of-growing-stock cooperative study in Douglas-fir: report no. 9—some comparisons of DFSIM estimates with growth in the levels-of-growing-stock study. Res. Pap. PNW-RP-376. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 34 p.

Initial stand statistics for the LOGS study installations were projected by the DFSIM simulation program over the available periods of observation. Estimates were compared with observed volume and basal area growth, diameter change, and mortality. Overall agreement was reasonably good, although results indicate some biases and a need for revisions in the DFSIM program.

**Marshall, David D.; Bell, John F.; Tappeiner, John C. 1992.** Levels-of-growing-stock cooperative study in Douglas-fir: report no. 10—the Hoskins study, 1963-83. Res. Pap. PNW-RP-448. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 65 p.

Results of the Hoskins study are summarized through the fifth and final planned treatment period. To age 40, thinnings in this low site I stand resulted in large increases in diameter growth with reductions in basal area and cubic volume growth and yield. Growth was strongly related to level of growing stock. All treatments are still far from culmination of mean annual increment in cubic feet.

**Curtis, Robert O. 1992.** Levels-of-growing stock cooperative study in Douglas-fir: report no. 11—Stampede Creek: a 20-year progress report. Res. Pap. PNW-RP-442. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 47 p.

Results of the first 20 years of the Stampede Creek study in southwest Oregon are summarized. To age 53, growth in this site III Douglas-fir stand has been strongly related to level of growing stock. Marked differences in volume distribution by tree sizes are developing as a result of thinning. Periodic annual increment is about twice mean annual increment in all treatments, indicating that the stand is still far from culmination.

## Contents

## Introduction

The Iron Creek levels-of-growing-stock (LOGS) installation is one of nine installations in a regional thinning study established in young even-aged Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) stands according to a common work plan (report no. 1—Williamson and Staebler 1971; appendix 1 in this report; fig. 1).[1] This study is a cooperative effort involving Canadian Forest Service, Oregon State University, USDA Forest Service, Washington State Department of Natural Resources, and Weyerhaueser Company. The objective is to compare growth-growing stock relations, cumulative wood production, and tree size development under eight different thinning regimes begun before the onset of severe competition. The original study plan was developed at Weyerhaeuser Company, Centralia, Washington. Procedural details were developed by the Pacific Northwest Research Station, USDA Forest Service, Portland, Oregon.

Detailed progress reports on individual installations are contained in the series of LOGS publications listed at the beginning of this report. Curtis and Marshall (1986) give an overall summary of results for the first 20 years of the program. Since 1986, several of the higher site installations, of which Iron Creek is one, have completed the full course of the experiment as originally planned.


Figure 1—Locations of the nine installations of the levels-of-growing-stock cooperative study in Douglas-fir.

[1] Staebler, George R; Williamson, Richard L. 1962. Plan for a level-of-growing-stock study in Douglas-fir. Unpublished study plan. On file with: Forestry Sciences Laboratory, 3625—93d Avenue SW, Olympia, WA 98512.

The Iron Creek LOGS installation was established in 1966 by the Pacific Northwest Research Station and the Pacific Northwest Region (Region 6) of the USDA Forest Service. Some preliminary data were given by Williamson (report no. 4—1976) and by Williamson and Curtis (report no. 7—1984). At the end of the 1989 growing season, Iron Creek had completed the fifth and final treatment period of the experiment as originally planned.

The purposes of this report are to document the quantitative results obtained and to present and discuss the implications of results through the final treatment period.

## Objectives

The LOGS cooperative studies evolved from work in the late 1950s by George Staebler (1959, 1960). Staebler argued that thinning would transfer increment to the remaining faster growing trees and increase growth percent through reduction in growing stock, while largely eliminating mortality losses. He also recognized that the implied assumption of near-constant gross increment over a wide range of stocking had not been tested. The objectives of the LOGS studies, as stated in the 1962 plan, were "to determine how the amount of growing stock retained in repeatedly thinned stands of Douglas-fir affects cumulative wood production, tree size, and growth-growing stock ratios." Treatments were designed to include a wide range of growing stock so that the results would show "how to produce any combination of factors deemed optimum from a management standpoint." The study was not designed as a test of specific operational thinning regimes but was intended to define the quantitative relations between growth and growing stock for a closely controlled initial stand condition and kind of thinning.

## Methods

### Description of Study Area

The Iron Creek LOGS installation was established in 1966 in a Douglas-fir plantation located in section 30, T. 11 N., R. 7 E., Randle Ranger District, Gifford Pinchot National Forest. Stand age was 17 years since planting in 1949; 19 years from seed. Composition at time of establishment was recorded as nearly pure Douglas-fir; however, there evidently was abundant natural seeding of western hemlock (*Tsuga heterophylla* (Raf.) Sarg.) and redcedar (*Thuja plicata* Donn ex D. Donn) that had not yet reached sufficient size to be retained in the calibration cut, as shown by large numbers in an understory position now present on the control plots.

The stand is in a midslope position at an elevation of about 2,500 feet. Aspect is easterly, with slopes averaging about 25 percent. The plant association (Topik and others 1986) is western hemlock/swordfern (TSHE/POMU, *Tsuga heterophylla/ Polystichum munitum*). Estimated site index as of 1989 (King 1966) was 126 (base age 50 years breast height [b.h.]), or mid-site II.

The deep, well-drained soil (series undetermined) is derived from volcanic ash and lapilli overlying a residual soil developed on fractured volcanic rock. Surface soils range from sandy loam to loam, with interbedded pumice.

At the time the study was established, many trees had been damaged by bear. About 20 percent of the trees remaining after the calibration thinning had some injury. The area was then fenced, and further injury was limited to one episode after damage to the fence in 1975. By 1989, few of the remaining trees showed noticeable evidence of bear damage, although butt scars still could be found.

The May 1980 eruption of Mount St. Helens deposited about 1 inch of ash on the study area. Foliage was still ash covered the following September.

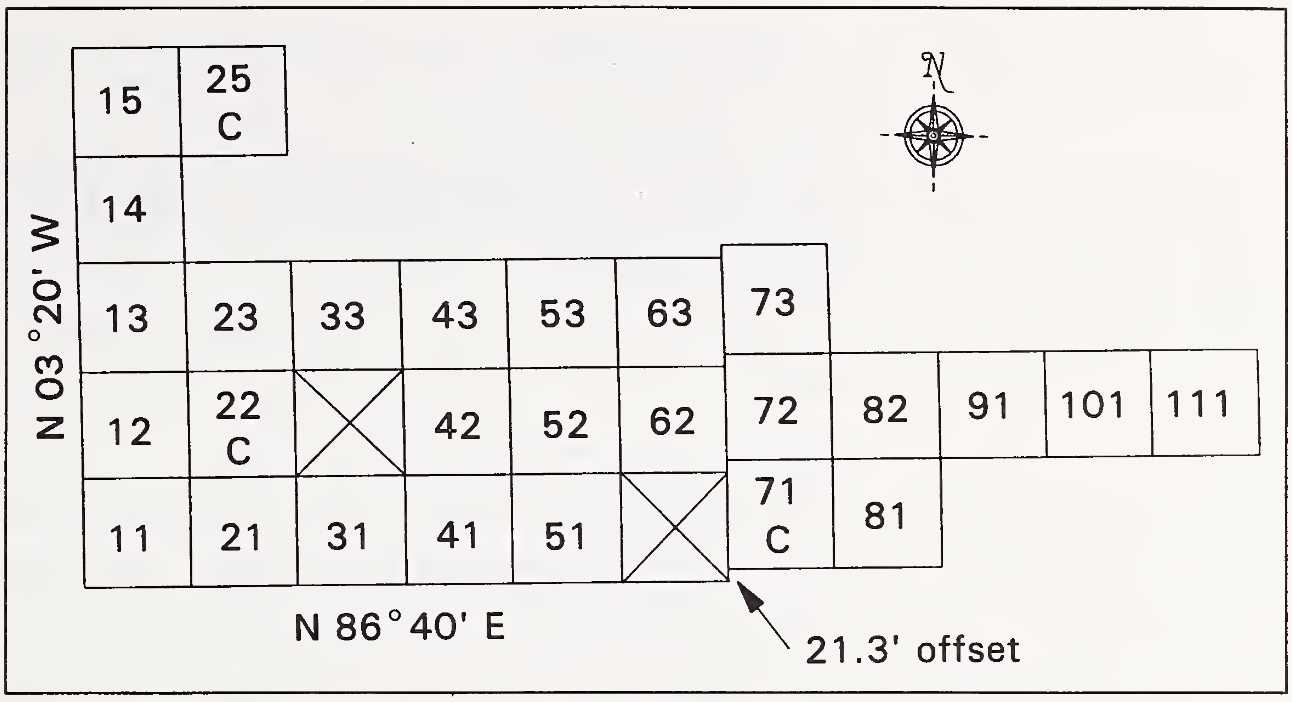


Figure 2—Arrangement of plots in the Iron Creek LOGS installation.

Several plots have had substantial damage from root rot. One plot (plot 51 in treatment 1) has been virtually destroyed by *Phellinus weirii* and has been excluded from analyses. Redcedar and hemlock reproduction is now abundant in the openings created by root rot and as a developing understory in the more heavily thinned treatments.

## Experimental Design

The experiment is a completely randomized design having three replications of eight thinning treatments, plus control. The 27 plots are one-fifth of an acre, square, without buffers except that a 30-foot isolation strip was provided around the outer margins of the experimental area. Physical arrangement is shown in figure 2. Detailed criteria (appendix 1) for area and plot selection provided a high degree of uniformity in initial conditions.

## Stand Treatments

Treatments were rigidly controlled to provide compatibility among installations on different sites.

**Selection of crop trees—**Crop trees were selected at the rate of 16 per plot (80 per acre), distributed to provide 4 well-spaced crop trees in each quarter of a plot. Crop trees were identified with white paint bands.

**Calibration thinning—**An initial calibration thinning was made on the 24 plots assigned to thinning treatments and was intended to reduce all to as nearly comparable condition as possible. All trees less than one-half the initial stand quadratic mean diameter (QMD) were cut. Additional noncrop trees were cut as needed to meet the study plan specifications, which called for the stand to be thinned to an initial spacing based on the equation,

$$S = 0.6167 \times QMD + 8 ,$$

where S is the average spacing in feet and QMD is quadratic mean diameter of the leave trees. Marking was controlled by the specifications that QMD of the leave trees should be within 15 percent of the installation mean, and leave tree basal areas should be within 3 percent. All leave trees on thinned plots were identified with permanent numbered tags. Trees 1.6 inches diameter at breast height (d.b.h.) and larger were tagged on the control plots.

Treatment thinnings—Treatment thinnings were made in 1970, 1973, 1977, 1980, and 1984 (ages 23, 26, 30, 33, and 37, respectively), which corresponded to about 10-foot increments in crop tree height. Thinning intensity was determined as percentages of gross basal area growth on the control plots, as defined in the table on the inside front cover. Gross basal area growth of controls was assumed to represent the productive potential of the site at full stocking. Basal areas after thinning were calculated from the equation,

$$BA_n = BA_{(n-1)} + p \times GBAG \, ,$$

where

$BA_n$ = basal area retained after thinning,

$BA_{(n-1)}$ = basal area at beginning of preceding treatment period,

p = prespecified percentage of gross basal area growth of controls to be retained, and

GBAG = average gross basal area growth on controls.

The expected trends in basal area created by these specifications are shown in figure 3.

Kind of thinning was further specified by the following requirements:

1. No crop trees were to be cut until all noncrop trees had been removed.

2. Average diameter of trees removed in thinning should approximate the average diameter of trees available for thinning (that is, noncrop trees only until all noncrop trees had been removed). This resulted in a d/D ratio (ratio of diameter of trees cut to diameter of stand before thinning) of less than 1.0 for the stand.

3. Trees removed in thinning were to be distributed across the range of diameters of trees available for thinning.

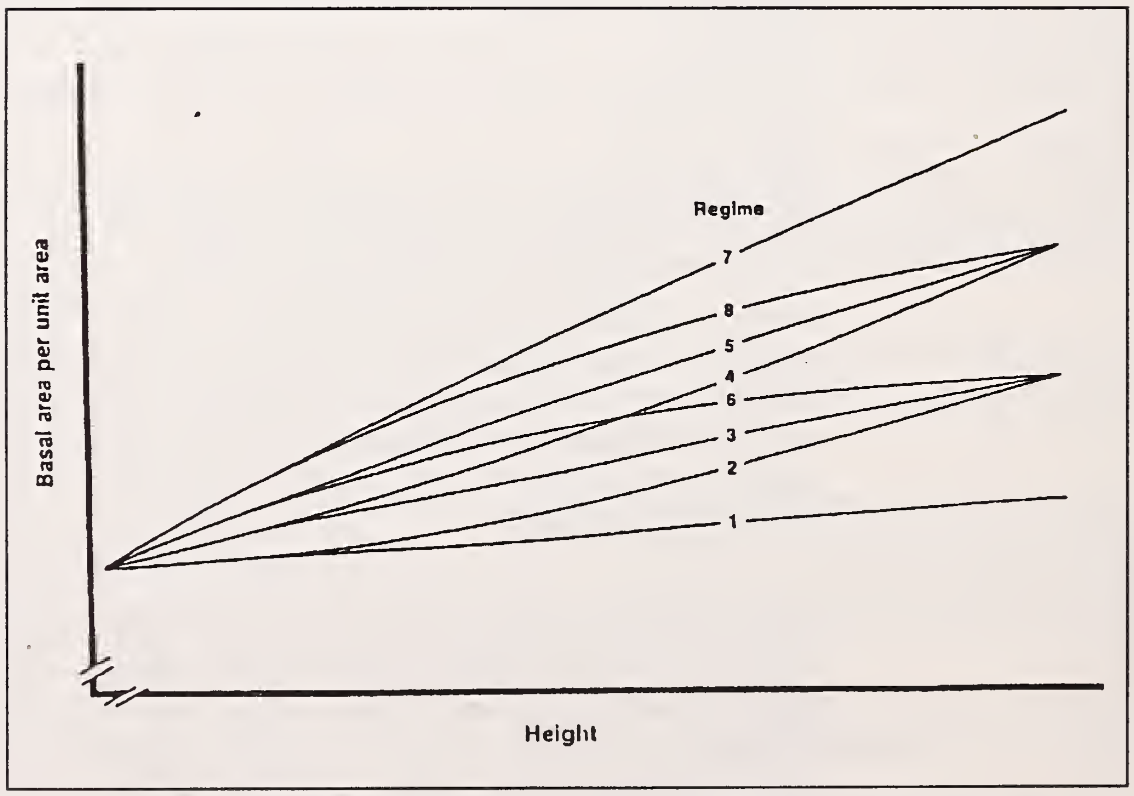


Figure 3—Idealized trends in basal area for the eight thinning regimes in the LOGS study.

The thinning specifications of the study plan were expected to result in a crown thinning. The d/D ratios were calculated for each of the five treatment thinnings. Overall means were about 0.90 with no clear trends over time or treatment.

### Data Collection and Summarization

Immediately after the calibration thinning, and at all subsequent measurement dates (that is, 1966, 1970, 1973, 1977, 1980, 1984, 1989), diameters of all tagged trees were measured to the nearest 0.1 inch. Ingrowth was tagged and measured on the control plots only. Heights were measured on a sample of these trees; sample size differed but was not less than 12 trees per plot, and usually more, distributed across the range of diameters. Beginning with the 1973 measurement, heights to base of live crown also were measured.

Constrained height-diameter curves were fit to each measurement on each plot with an adaptation[2] of Hyink and others' (1988) procedure. Tree volumes in total cubic feet inside bark (CVTS) were calculated by the Bruce and DeMars (1974) equation, from actual measured heights when available and from heights predicted by the Clendenen equations for trees not having measured heights. These were converted to merchantable cubic volumes to a 6-inch top (CV6) by using equations from Brackett (1973).

Stand heights were characterized as average height (H40) of the largest 40 trees (by d.b.h.) per acre for each plot and were calculated as the mean of the measured or estimated heights of all trees in this category.

### Analyses

The original study plan specified analysis of variance as the method of analysis. Many aspects of the experiment are more meaningfully presented and interpreted, however, through simple graphic comparisons of means and by regressions of periodic annual increment in basal area and in volume on basal area at period midpoints, by treatments. Regressions were of the form,

$$\ln Y = a + b \ln X + cX ,$$

as used previously by Curtis and Marshall (report no. 8—1986). The underlying numerical values are summarized in a series of tables given in appendix 2.

## Results

### Analysis of Variance

The analysis of variance is presented in tables 1 and 2 (all tables are in appendix 2). This follows the procedure outlined in the original study plan and used in previous LOGS reports (report no. 8—Curtis and Marshall 1986; report no. 10—Marshall and others 1992), except for changes made necessary by loss of one plot. This is a repeated-measures experiment that is computationally similar to a split-plot design (Snedecor and Cochran 1980), in which the periodic remeasurements correspond to subplots. Computations were done with the GLM procedure of SAS (SAS Institute 1988) and used as successive response variables periodic annual gross increment in cubic volume and corresponding growth percent, periodic annual gross increment in basal area and corresponding growth percent, and periodic annual net increment in quadratic mean diameter.

The interactions period x (fixed vs. variable), period x (between increasing), and period x (between decreasing) were in general nonsignificant. The corresponding main effect fixed vs. variable treatments was nonsignificant, thereby indicating no difference in overall means. Differences in means between increasing treatments, and those between decreasing treatments, are significant or nearly so for all variables.

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[2] Developed by Gary W. Clendenen and David D. Marshall.

The interactions period x fixed (linear) and period x (increasing vs. decreasing treatments) were significant in most cases. This indicates that, as would be expected, the relations differ over time. Consequently, the corresponding main effects, though statistically significant, are not meaningful. Interpretations are therefore made in terms of the graphic comparisons and regressions of growth on growing stock, by treatments, presented below.

## Trends in Live Stand Statistics

**Height of largest 40 trees per acre (H40)**—H40, defined as the average of the heights of the largest (by d.b.h.) 40 trees per acre, is a useful measure of height development. This can be calculated objectively for all plots from the data available, is little affected by thinning, and is now quite commonly used as the basis for site index estimates in the region.

Excluding plot 51 (severely damaged by root rot), the range in 1989 heights (age 42) was from 95 to 106 feet. There appeared to be no relation to thinning treatment. Mean of the thinned plots differed by only 0.2 foot from the mean of the controls (table 3).

Figure 4 compares development of H40 over the life of the installation with that predicted by King (1966) for site index 126. The curves are nearly identical.

**Number of trees**—Trends over time in trees per acre by thinning treatments are shown in figure 5. Corresponding numerical values, including those for the controls (omitted in fig. 5), are given in table 4.

**Basal area**—Corresponding values of basal area per acre, by treatments, are shown in figure 6 and in table 5.

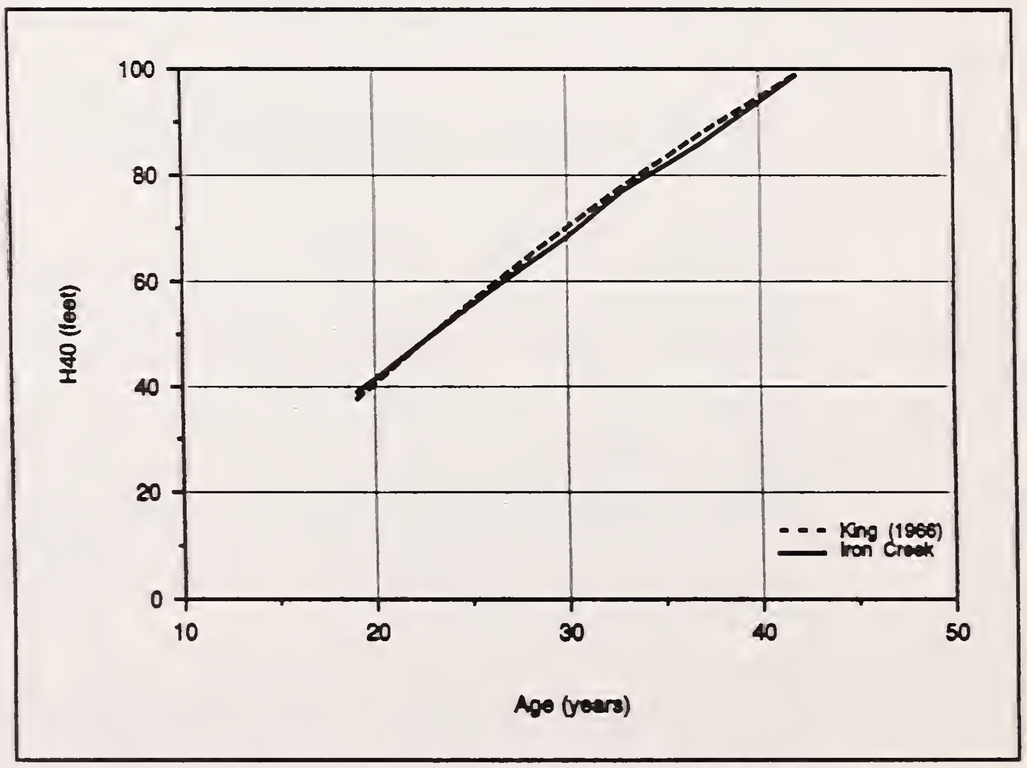


Figure 4—Observed H40 trend compared to King (1966) predicted heights.

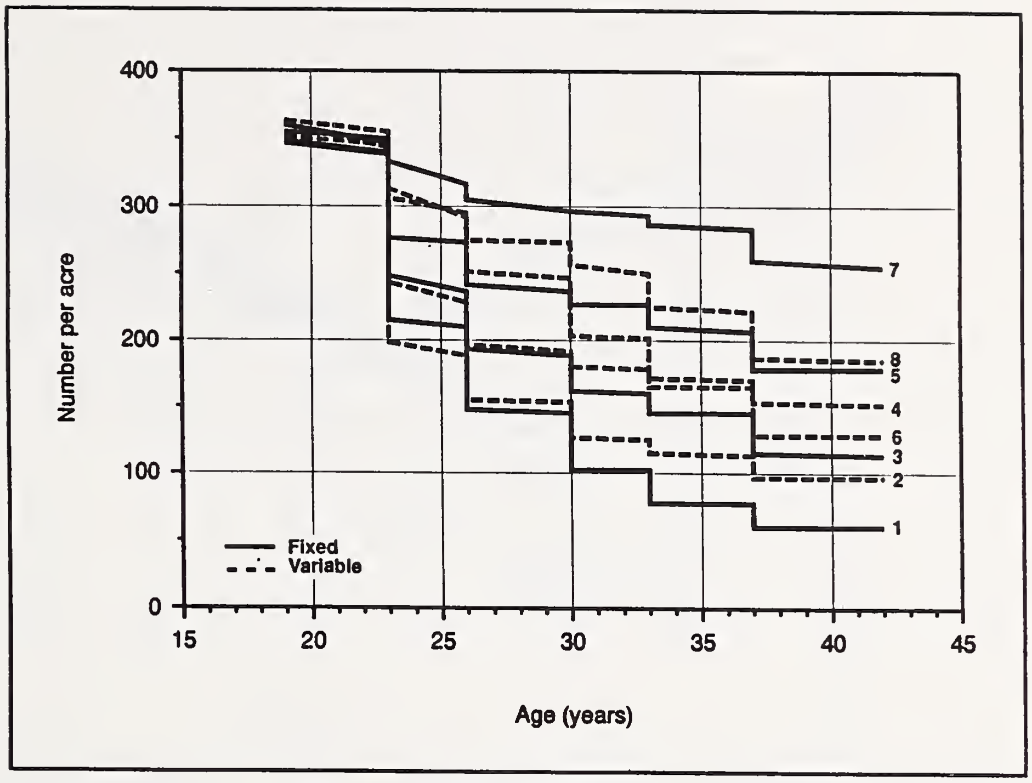


Figure 5—Numbers of trees per acre by treatment and age.

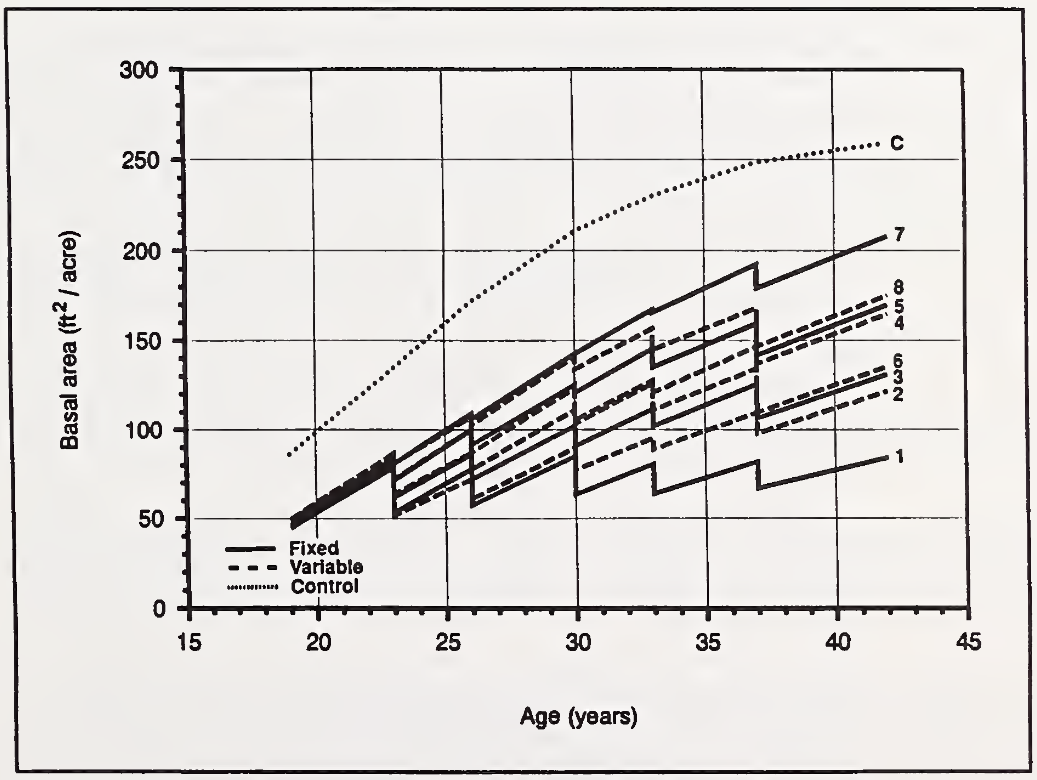


Figure 6—Trends of live basal area by treatment and age.

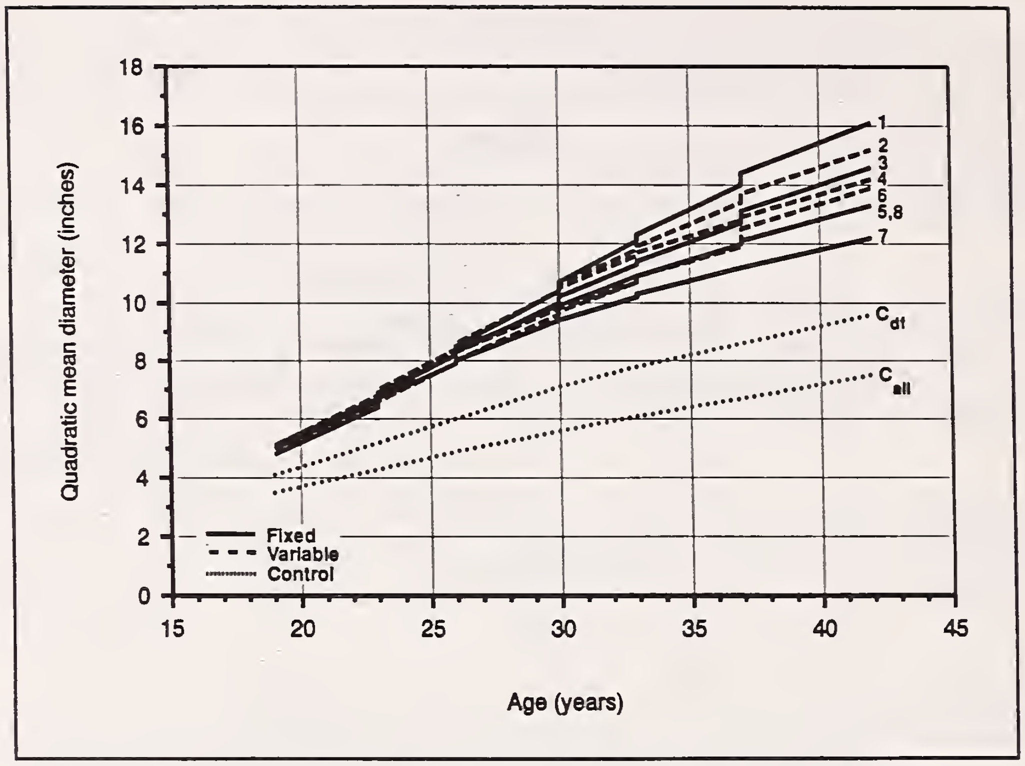


Figure 7—Attained quadratic mean diameters (QMD) by treatment and age.

**Quadratic mean diameter (QMD)**—Trends in quadratic mean diameter are shown in figure 7 and table 6. As discussed later, QMD values for the control are strongly influenced by presence of an understory of small stems of tolerant species. QMD of Douglas-fir only is a better measure of development relative to the thinned plots (which are almost pure Douglas-fir) than is QMD of all species.

**Other diameter measures**—Several other average diameters are sometimes used to express stand attributes. D40, average diameter of the 40 largest (by d.b.h.) trees per acre, corresponds to H40 and is useful in expressing effect of treatment on diameter growth of leading dominant trees. Unlike QMD, this is only slightly influenced by removal of trees through thinning or mortality, because few trees in this category are cut in the thinning regimes considered, and suppression mortality does not occur.

Trends in development of D40 over time are shown in figure 8 and table 7. Thinning has had much less effect on D40 than on QMD. Thinning, none the less, has had a consistent effect on diameter growth of these largest trees.

A second measure of diameter development is D80, quadratic mean diameter of the largest (by d.b.h.) 80 stems per acre. This is similar to D40, though somewhat smaller in value, and is sometimes used for similar purposes as a value roughly corresponding to the expected number of surviving trees at harvest age under some commonly used regimes.

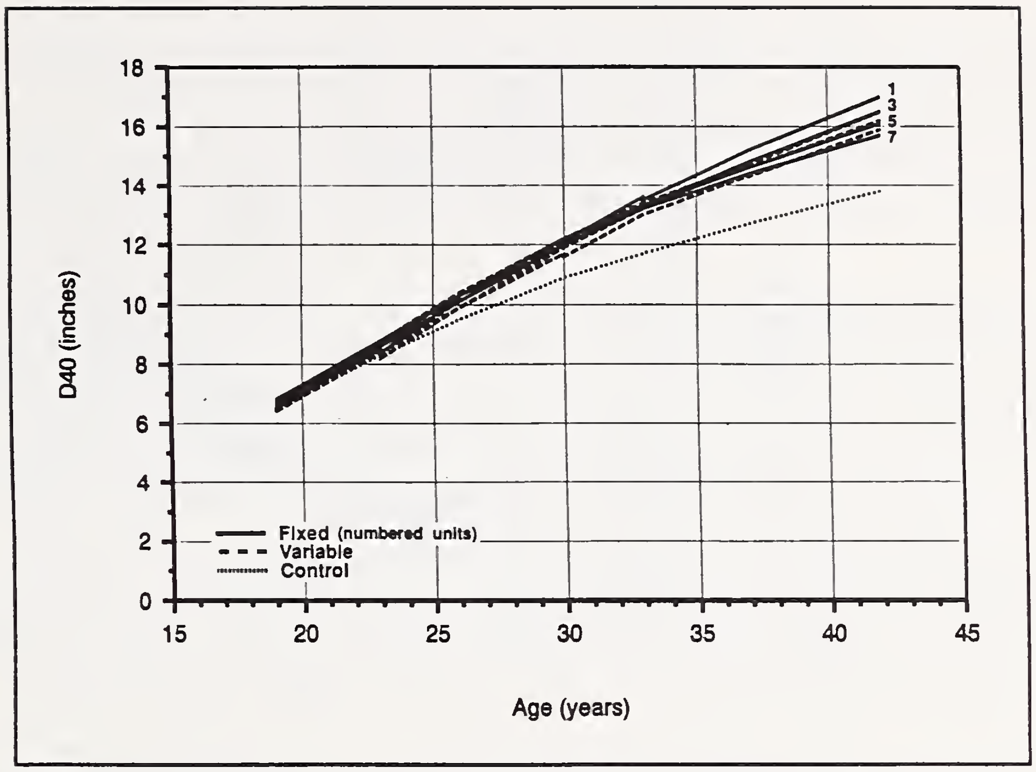


Figure 8—D40 (average diameter of largest 40 trees per acre) by treatment and age.

A third measure of diameter development is Dcrop, quadratic mean diameter of designated crop trees, shown in table 7. The study plan envisioned an initial selection of crop trees based on a combination of vigor and spacing, with these trees to be favored during thinning and retained to the end of the experiment. Although there were 80 such trees per acre, diameters were expected to be somewhat less than D80 because of the spacing constraint. Interpretation of this value is somewhat obscured by substitution of new crop trees for damaged and low-vigor trees, but values are given for comparability with other reports.

Both D80 and Dcrop values become equal to QMD once the number of stems (some treatments only) has been reduced to 80 per acre.

Total cubic volume (CVTS)—Trends in cubic volume of total stem are shown in figure 9, with numerical values given in tables 8 and 9.

**Merchantable cubic volume (CV6)**—Trends in merchantable cubic volume to a 6-inch top diameter inside bark (d.i.b.) are shown in figure 10; numerical values are in table 10.

## Relative Density Measures

Relative density measures are useful in describing thinning regimes, as guides for density control, as values interpretable as measures of competition, and as predictors of growth. Here, treatments were compared by using two common relative density measures that are nearly equivalent, except for scale factors. These are Curtis' (1982) relative density (RD) and Reineke's (1933) stand density index (SDI). Relative density is defined by the equation,

$$RD = \frac{\text{basal area}}{\sqrt{\text{QMD}}},$$

and is merely a rearrangement of Reineke's equation (with a slight difference in exponent) into a form that some find easier to use.

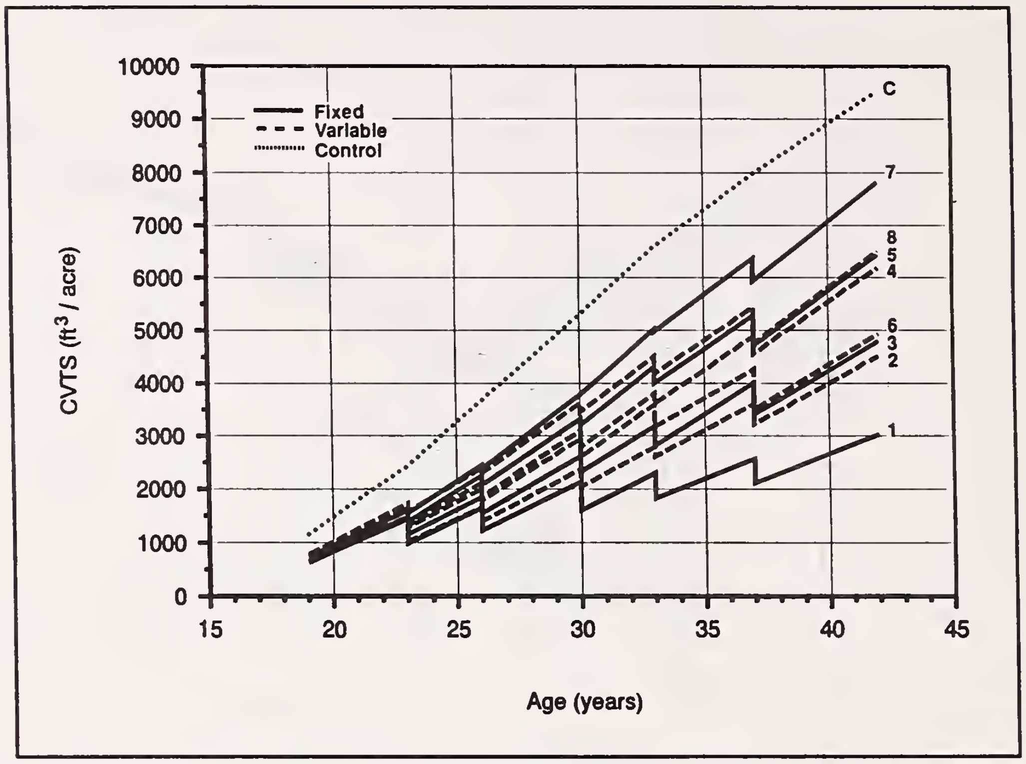


Figure 9—Total stem volume (CVTS) in live trees, by treatment and age.

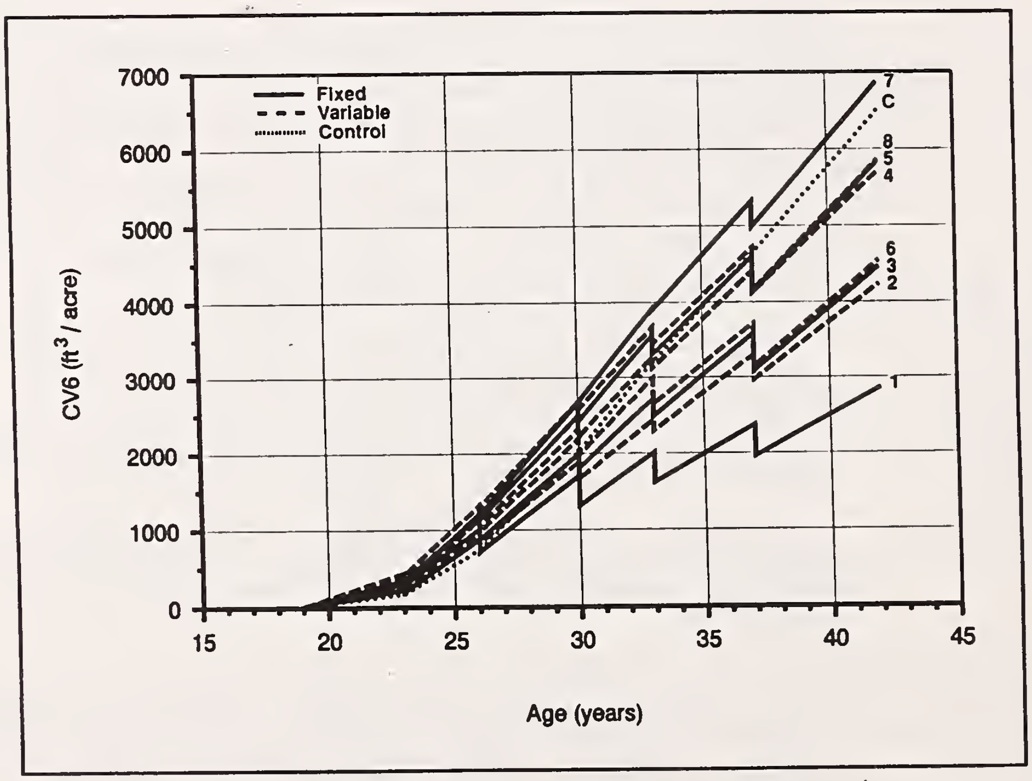


Figure 10—Merchantable volume (CV6) in live trees, by treatment and age.

Figures 11 and 12 display trends of RD over time for the various thinning regimes. The corresponding trends for the control are useful as reference points for thinning regimes (that is, their relation to "maximum"), and the asymptote represents an estimate of the maximum attainable density in an unthinned stand at this location. This differs among locations and is not closely related to site index (report no. 8—Curtis and Marshall 1986).

The diameter distribution (fig. 13) for the Iron Creek control plots illustrates a mensurational problem of common occurrence in western Washington. The main stand consists of Douglas-fir, with an understory of tolerant species—western hemlock and redcedar. The understory trees contribute little to volume and basal area (13 percent of basal area at age 42) and almost nothing to volume or basal area growth, and have negligible effect on growth of the stand; but they do represent a large fraction of the total number of stems present (47 percent at age 42). This has a considerable effect on computation of QMD and of density measures, such as RD and SDI, that involve QMD; and can lead to grossly inflated values that are probably meaningless as indicators of stand-level competition. Thinned plots had understory removed at establishment, and ingrowth has not been measured; therefore, they are unaffected.

For the stand structures on the Iron Creek unthinned plots, several methods of adjustment are possible that give values approximating those for a stand with a more or less symmetrical diameter distribution and equivalent level of competition. One procedure is to truncate the distribution at a point that excludes most of the understory. At Iron Creek, a diameter of D40/3 seems a reasonable truncation point for all measurements. An alternative procedure is to calculate RD by using basal area of all trees (which is little influenced by the understory) and QMD of the Douglas-fir. For these data, results of the two procedures are nearly identical. The resulting curves (dashed lines in figs. 11 and 12) suggest that maximum RD for this stand is in the range RD80-85. The value of RD95 indicated by the calculation using all trees is almost certainly a gross overestimate of competition level.

**Reineke diagram**—Figures 14 and 15 show the trends of number in relation to QMD of all trees on log-log scales (Reineke 1933), by treatments. Truncation of the diameter distribution has no effect on values for thinning treatments but shifts the curve for the control down and to the right.

**Stand density index**—Figures 16 and 17 show the trends of SDI over time for the various thinning treatments. The trend of SDI for the control plots appears to be approaching a maximum value in the vicinity of SDI 500. As with RD, inclusion of small understory stems of a younger age class probably leads to an overestimate.

## Cumulative Volume Production

**Total cubic volume**—Cumulative total cubic volume production under the various treatments is shown in figure 18 and table 9. Estimated volume of material cut at the calibration thinning has been added to provide a common origin with the curve for the control. In the thinned treatments, mortality has been relatively slight and due to root rot rather than suppression, and gross production values differ only slightly from the net values shown.

Although net CVTS production on the control has been higher than on any of the thinning treatments, with the onset of suppression-related mortality, it is declining relative to the thinning treatments, and it seems likely that the higher density thinning treatments soon will cross the control curve.

*Text continued on page 16*

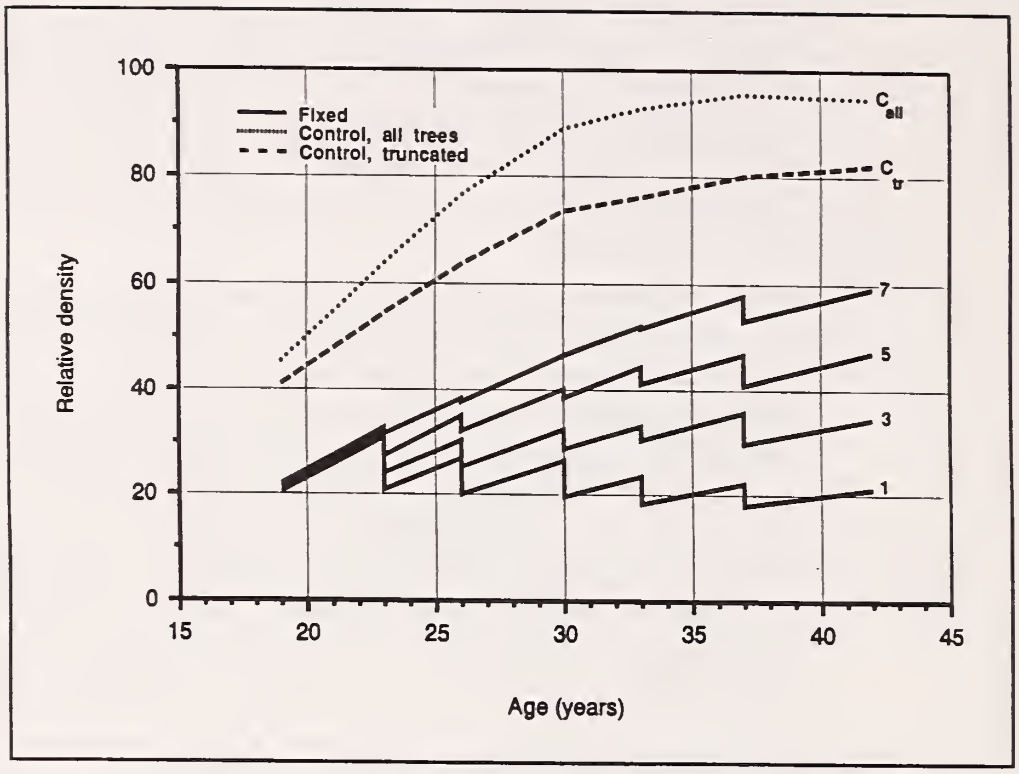


Figure 11—Trends in relative density (RD) in relation to age, for fixed treatments and control.

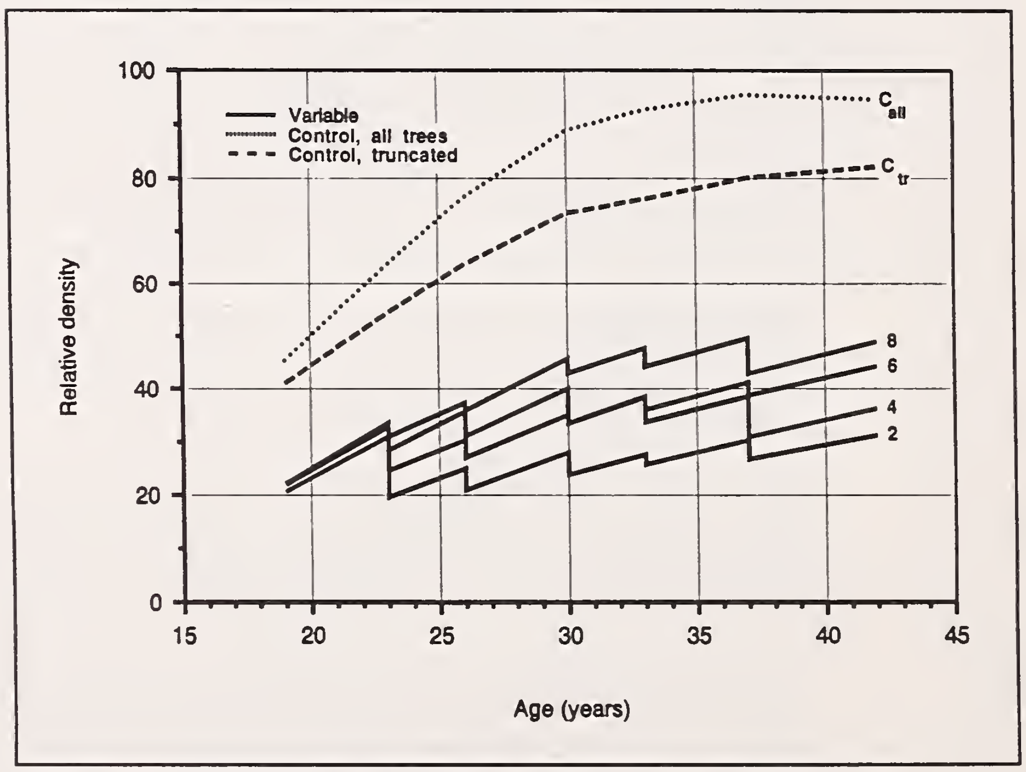


Figure 12—Trends in relative density (RD) in relation to age, for variable treatments and control.

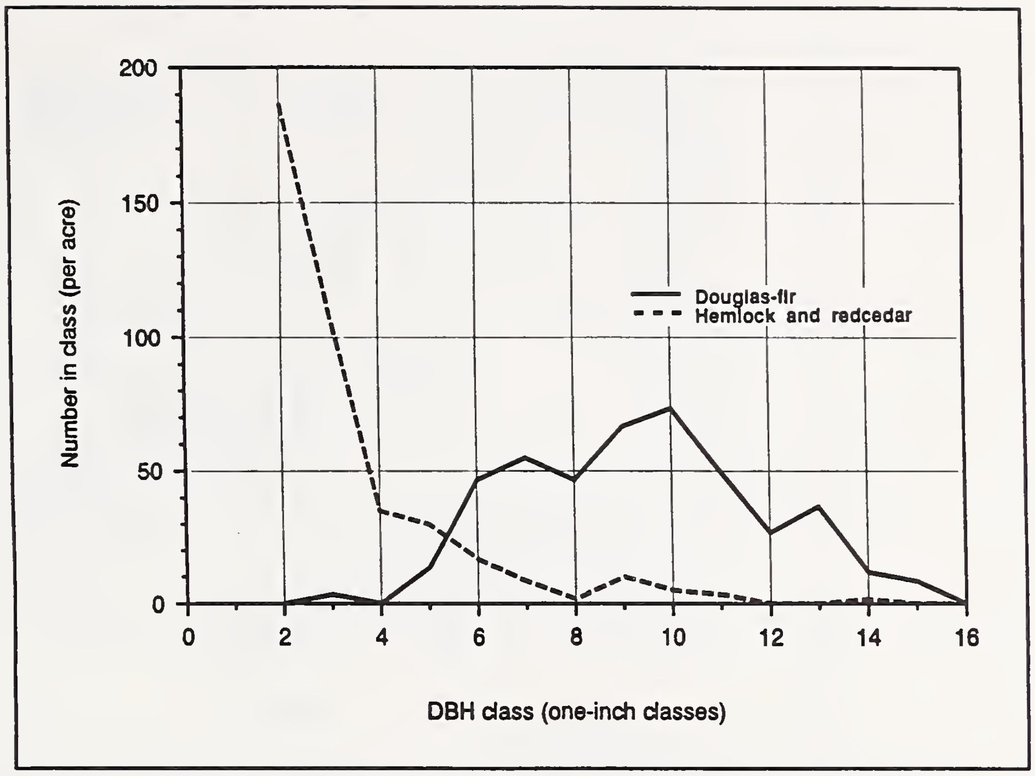


Figure 13—Numbers of trees on control in 1989, by diameter class and species group.

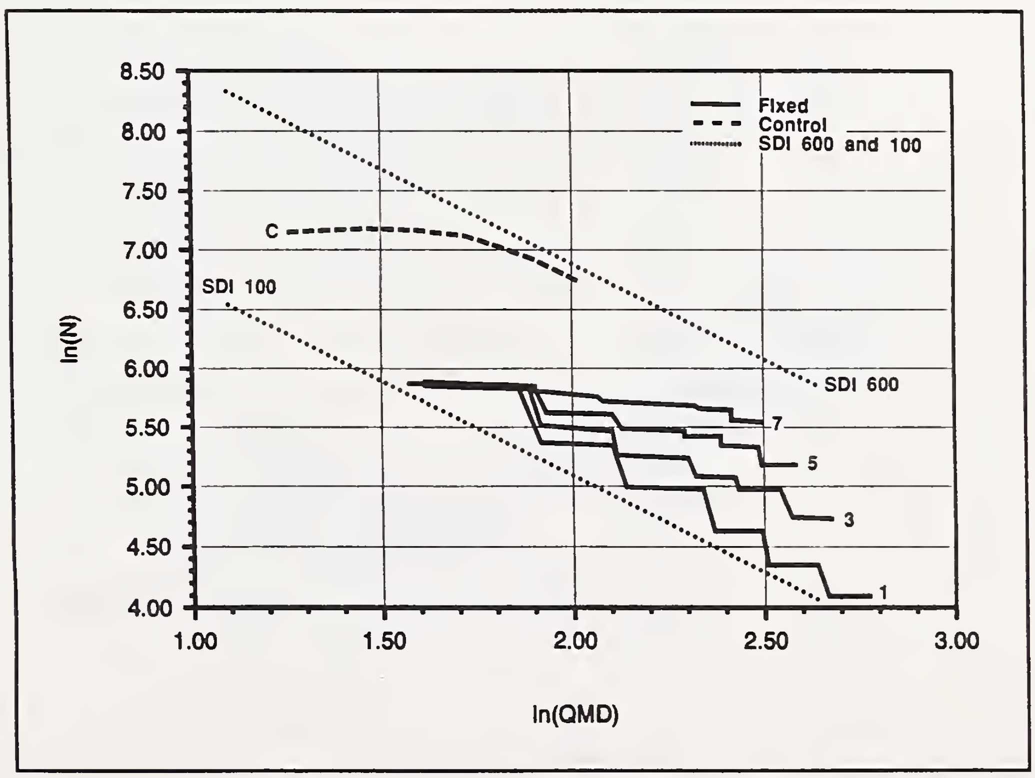


Figure 14—Reineke plot of ln (number of trees) over ln(QMD), for fixed treatments and control.

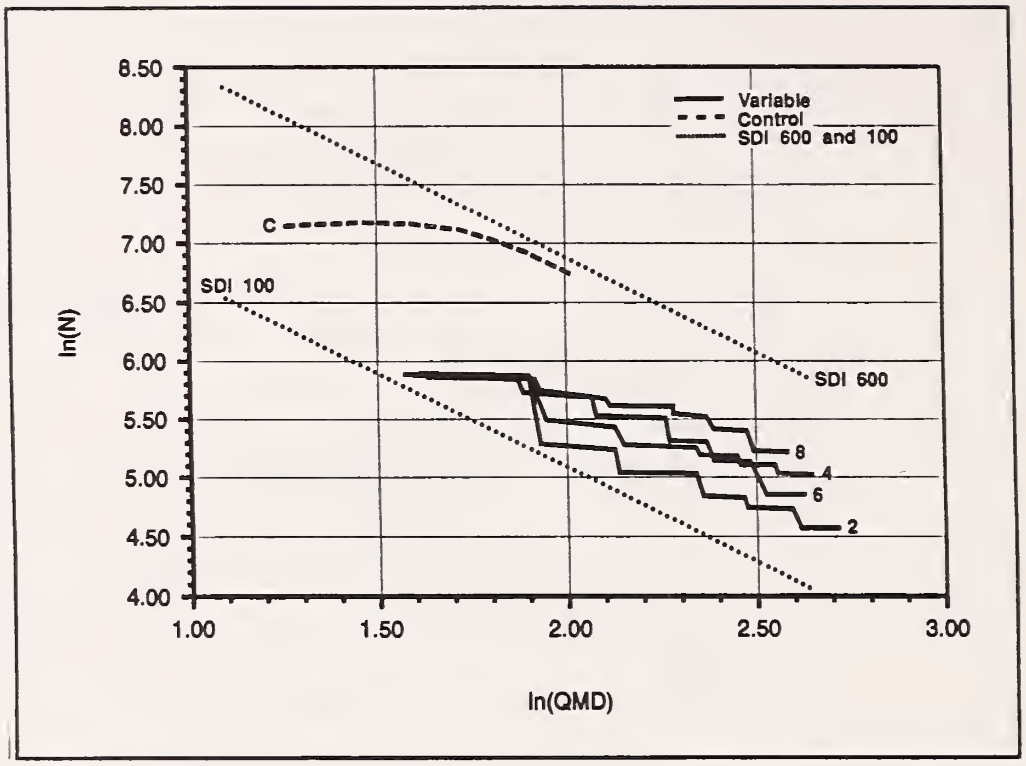


Figure 15—Reineke plot of ln(number of trees) over ln(QMD), for variable treatments and control.

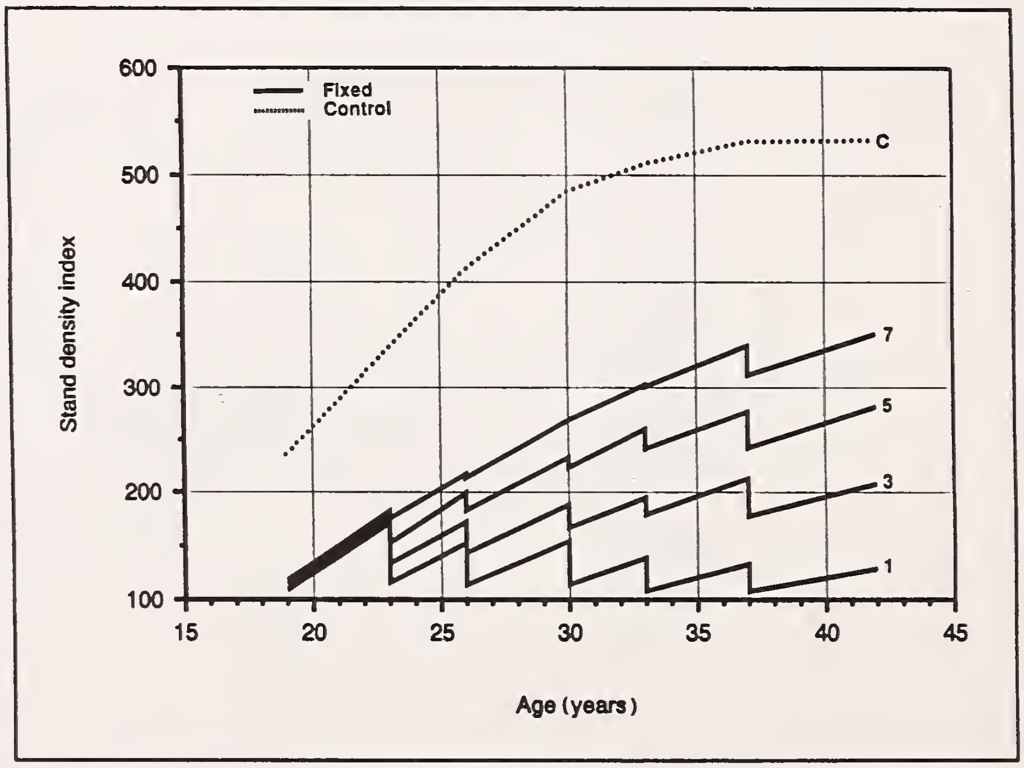


Figure 16—Stand density index (SDI) in relation to age, fixed treatments and control.

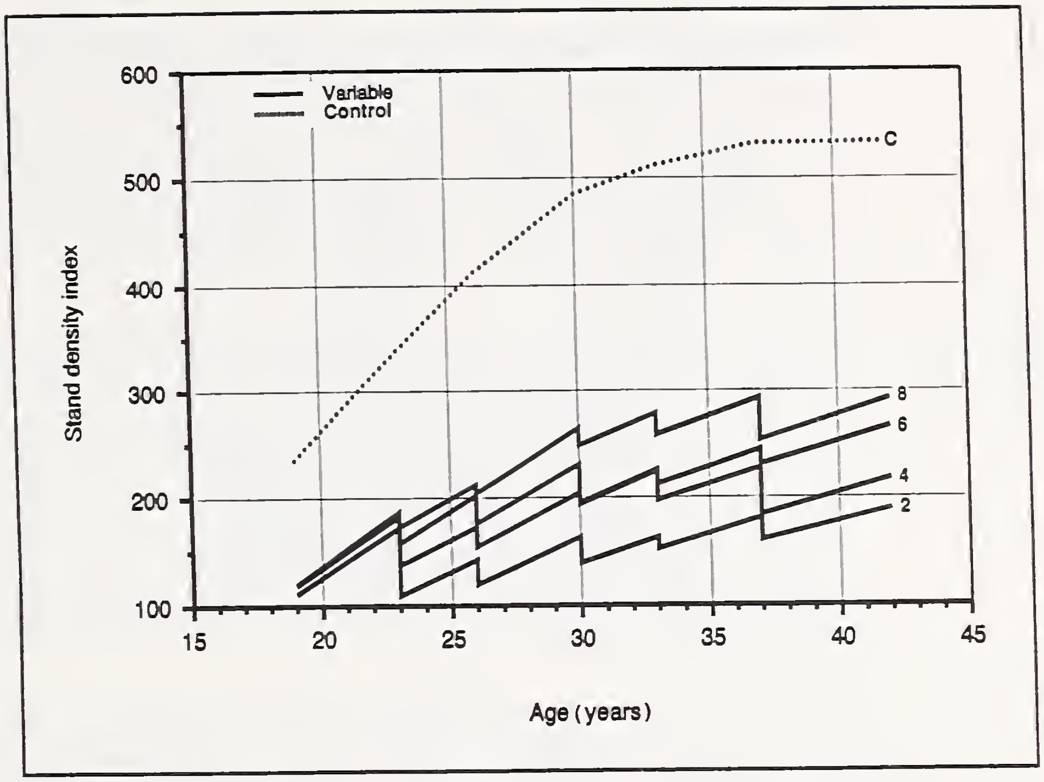


Figure 17—Stand density index (SDI) in relation to age, variable treatments and control.

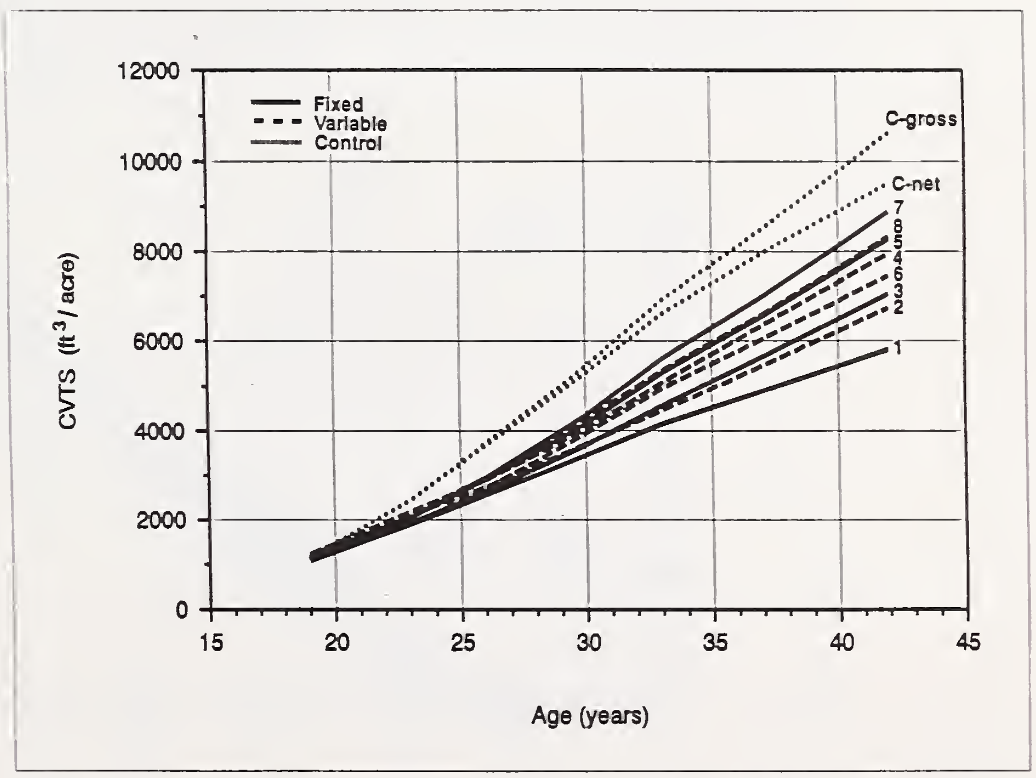


Figure 18—Cumulative net total volume (CVTS) production in relation to age, and treatment.

**Merchantable cubic volume**—Cumulative merchantable volume production for the various treatments is shown in figure 19 and table 9. All values are net. Treatments 5, 7, and 8 have exceeded the control volume, and treatment 4 has produced virtually the same volume as the control; all thinning treatments have produced considerably larger diameter trees. As yet suppression-related mortality has had little effect on the control because mortality has been principally in trees too small to contribute to CV6 totals.

## Volume Distribution by Tree Size Classes

Distribution of CVTS by tree size classes is shown in three graphs. Figure 20 shows volumes in live trees 15.6+, 13.6+, 11.6+, 9.6+, 7.6+, and 1.6+ inches d.b.h. at the end of the fifth treatment period (1989). Figure 21 shows corresponding cumulative totals—live stand in 1989 plus volumes of trees removed in thinnings. Figure 22 shows distribution at end of fifth treatment period (1989) as percentages of total live standing volume. Although thinned plots have produced less total volume than the control, and lower density thinned plots have produced less total volume than higher density plots, thinned plots have their volume concentrated on fewer but considerably larger trees.

## Periodic Annual Increment

Periodic annual increment (PAI) values presented are net. Mortality has been negligible on most thinned plots. There has been substantial suppression mortality on the controls, which is not presented here.

**PAI in basal area**—Time trends of net periodic annual increment in basal area are shown in figures 23 and 24 and in table 11, by treatments. Initially, the control is much above the others, but falls rapidly through the combination of reduced growth due to competition and increasing suppression mortality.

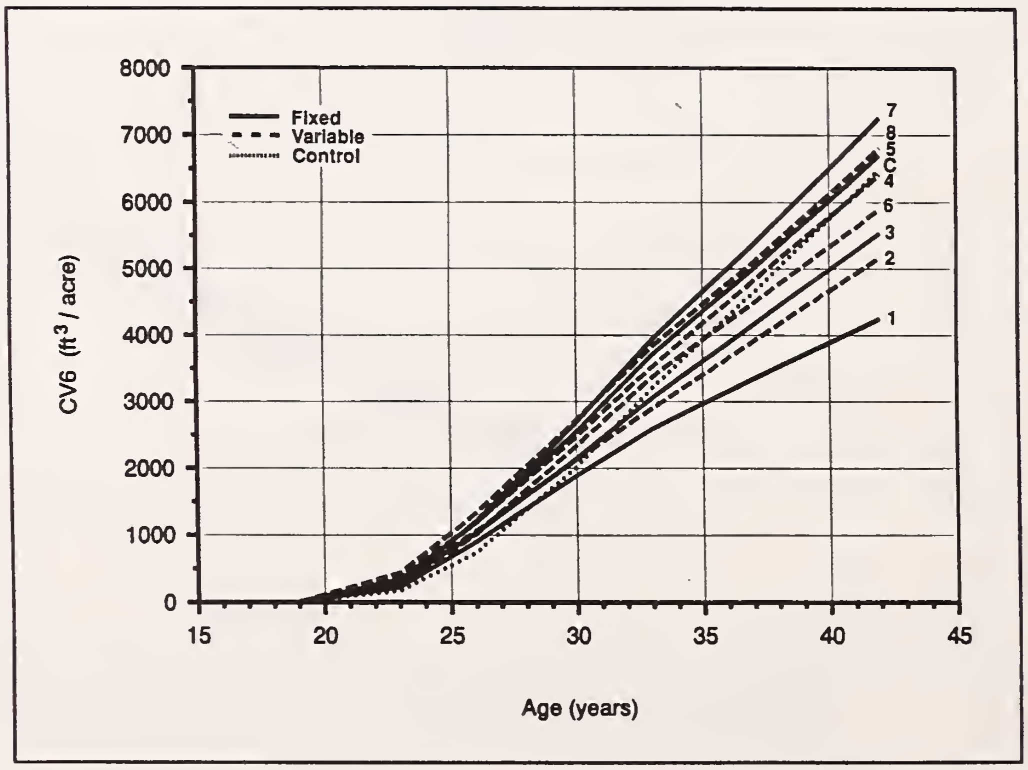


Figure 19—Cumulative net merchantable volume (CV6) production in relation to age and treatment.

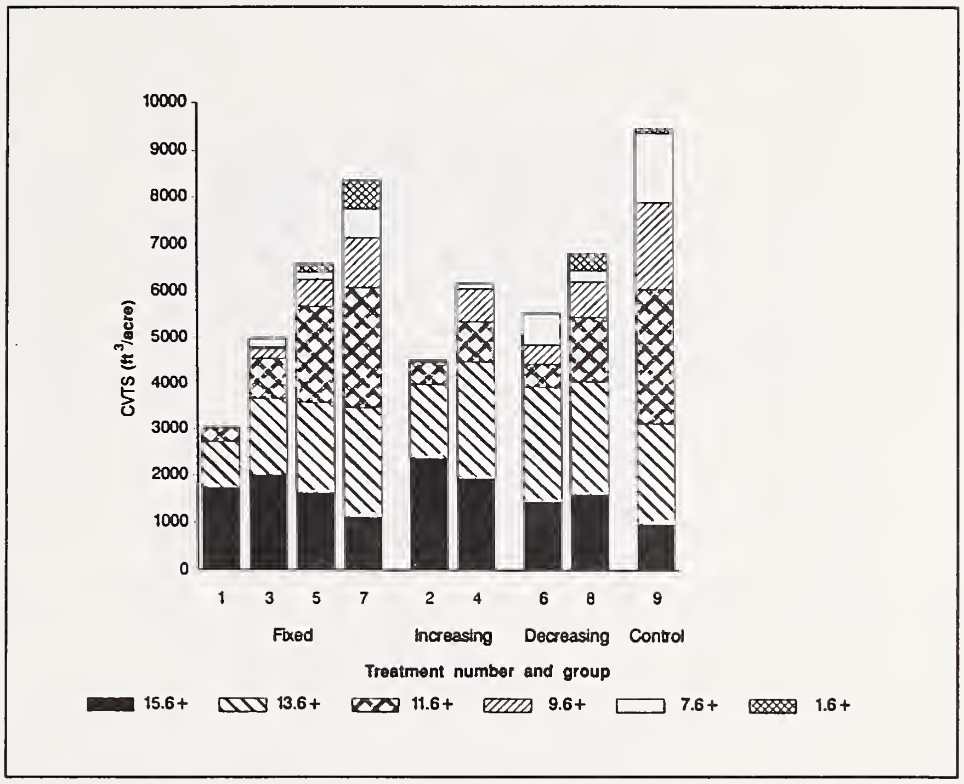


Figure 20—Distribution of total volume (CVTS) in live trees by size class and treatment, 1989.

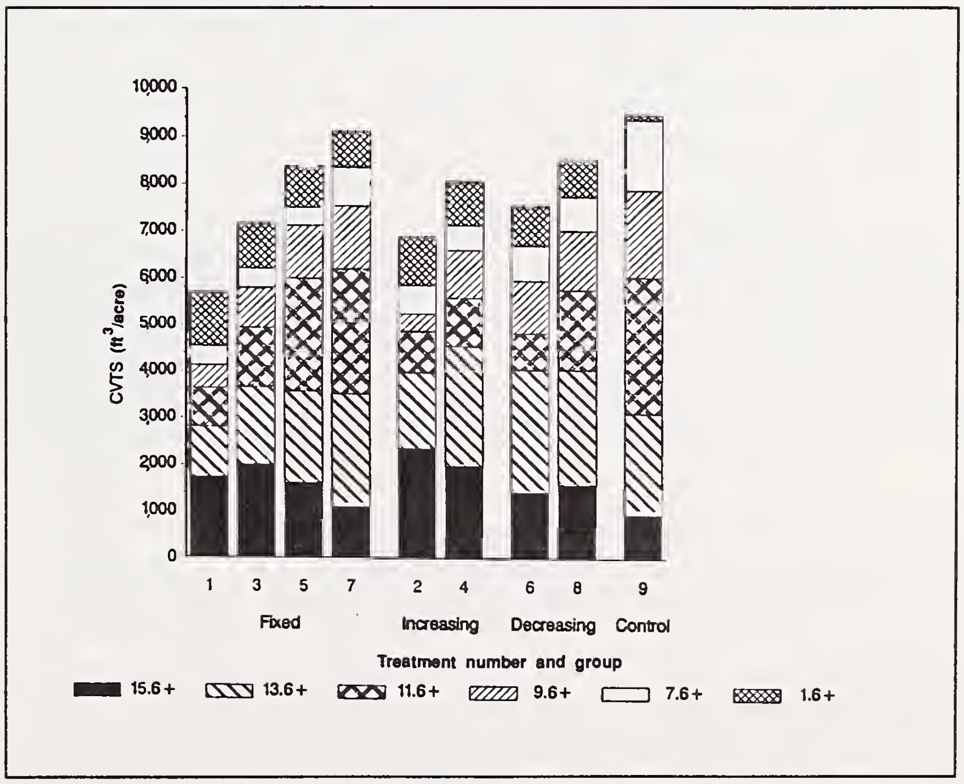


Figure 21—Cumulative production in total volume (CVTS) by tree size class and treatment, 1966-89.

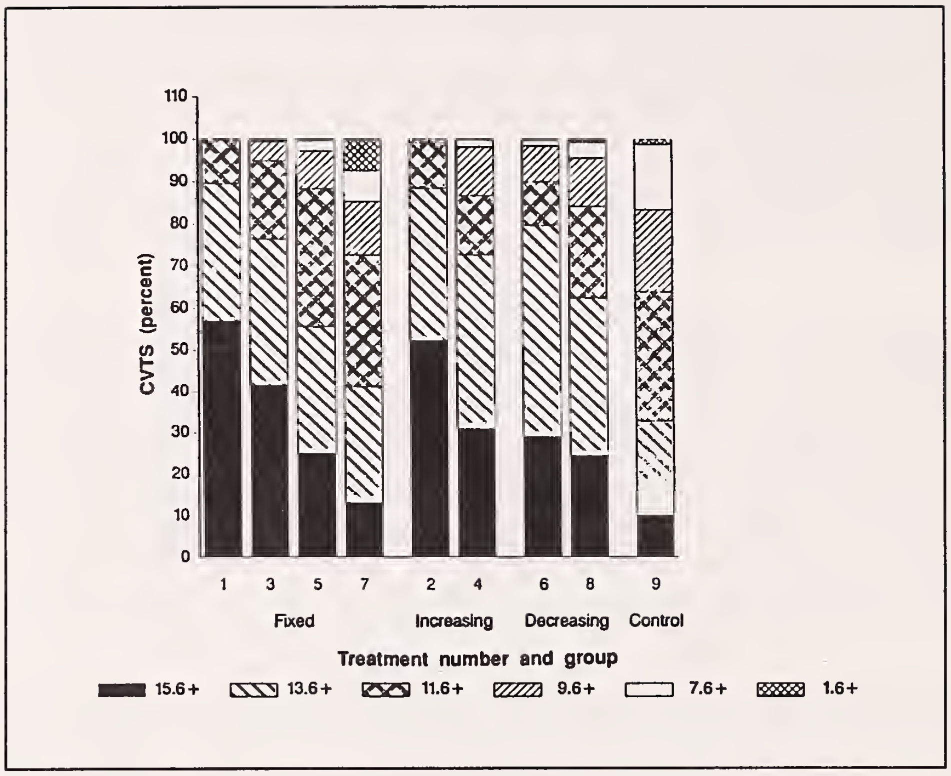


Figure 22—Percentage distribution of total volume (CVTS) by tree size and treatment, 1989.

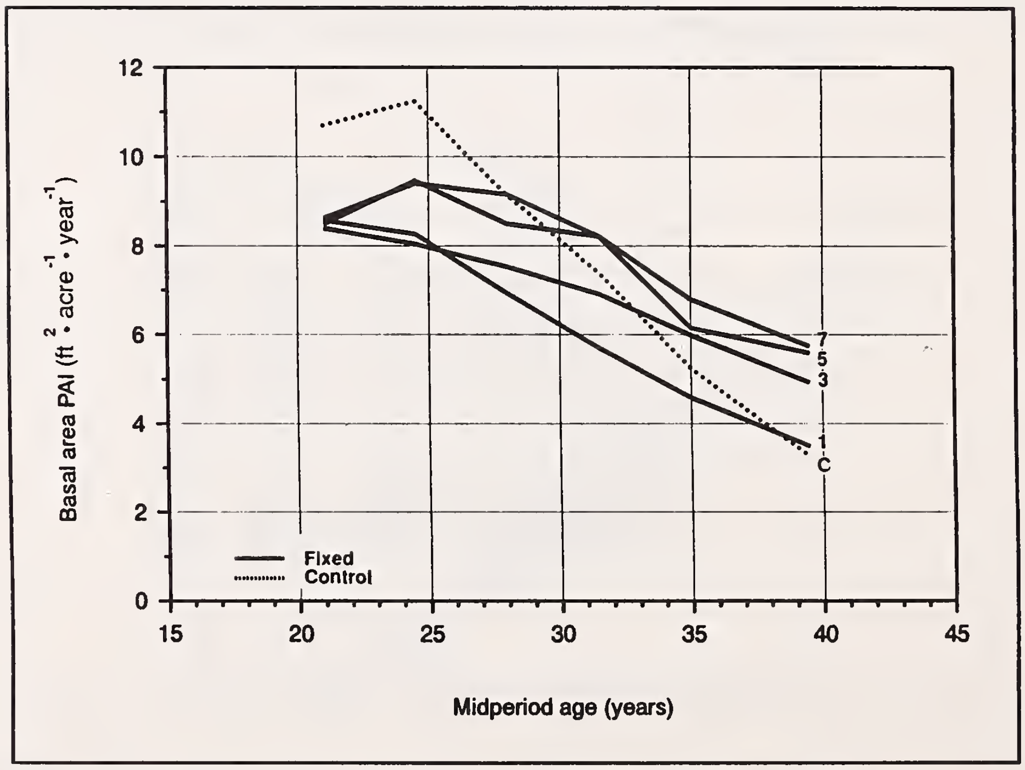


Figure 23—Net periodic annual increment in basal area in relation to age, fixed treatments and control.

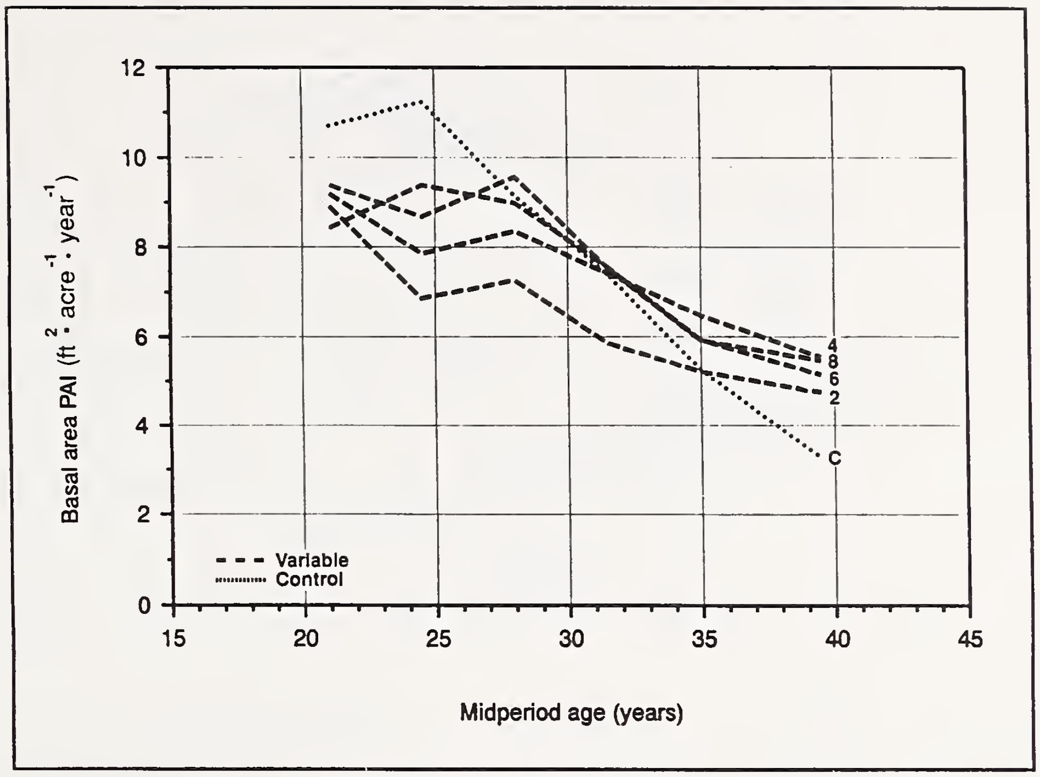


Figure 24—Net periodic annual increment in basal area in relation to age, variable treatments and control.

**PAI in quadratic mean diameter**—Time trends of periodic annual increment in QMD are shown in figures 25 and 26 and in table 12. For thinned plots, values of net change and of survivor growth are virtually identical, because there has been little mortality and no ingrowth. These values differ considerably for the control, however. Survivor growth is the more meaningful expression of actual biological growth (Curtis and Marshall 1989).

**PAI in total cubic volume**—Time trends of periodic annual increment in CVTS are shown in figures 27 and 28 and in table 13. Note the sharp depression in growth during the fourth treatment period. This reflects a corresponding depression in height growth in this period, as well as apparent slight reductions in basal area and diameter growth. This period represents the second through the fifth growing seasons following the Mount St. Helens ashfall and could possibly represent an aftereffect of the eruption.

**PAI in merchantable cubic volume**—Trends of CV6 PAI over time are shown in figures 29 and 30 and in table 13. The 6-inch merchantability limit markedly changes the shape of the curves, compared to that for CVTS.

**Periodic annual mortality**—Periodic annual mortality in number of trees, basal area, and CVTS is shown in tables 14 and 15. Values are low to negligible in all thinning treatments but became substantial on the unthinned plots in recent periods.

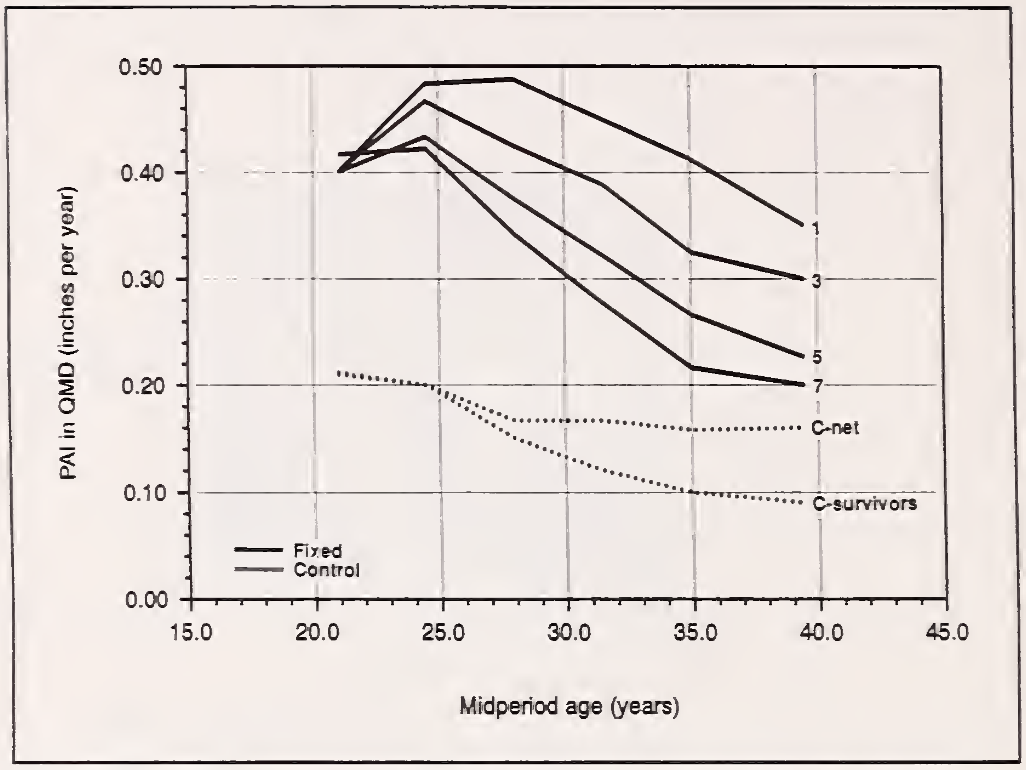


Figure 25—Periodic annual increment in quadratic mean diameter (QMD) in relation to age, fixed treatments and control.

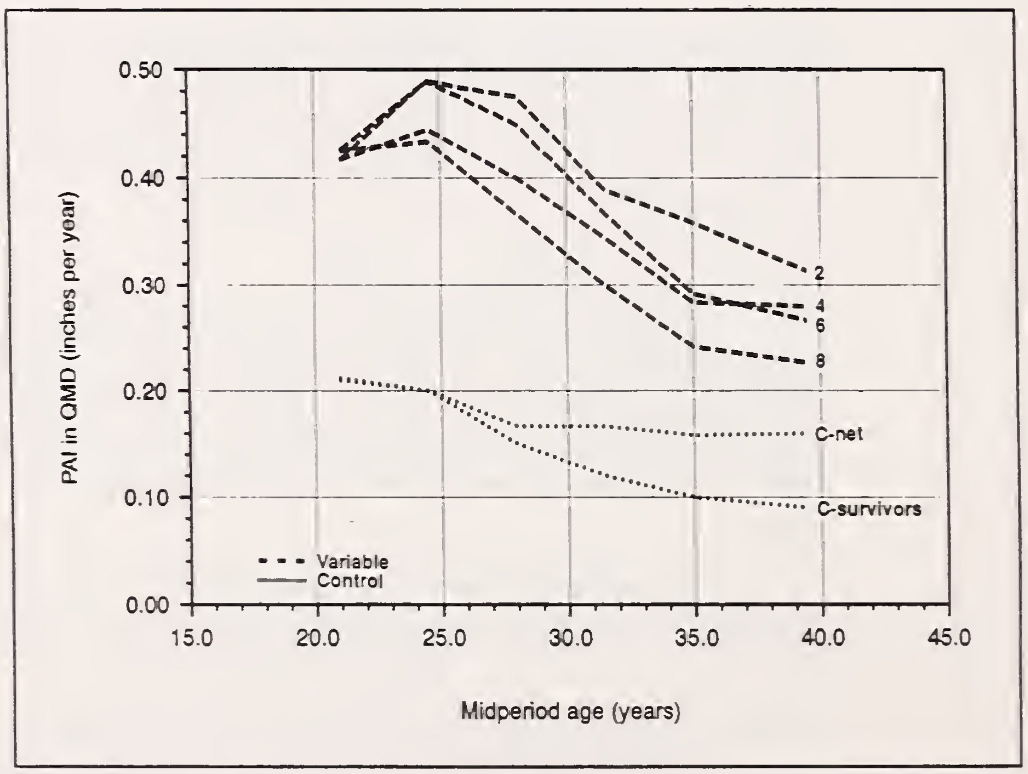


Figure 26—Periodic annual increment in quadratic mean diameter (QMD) in relation to age, variable treatments and control.

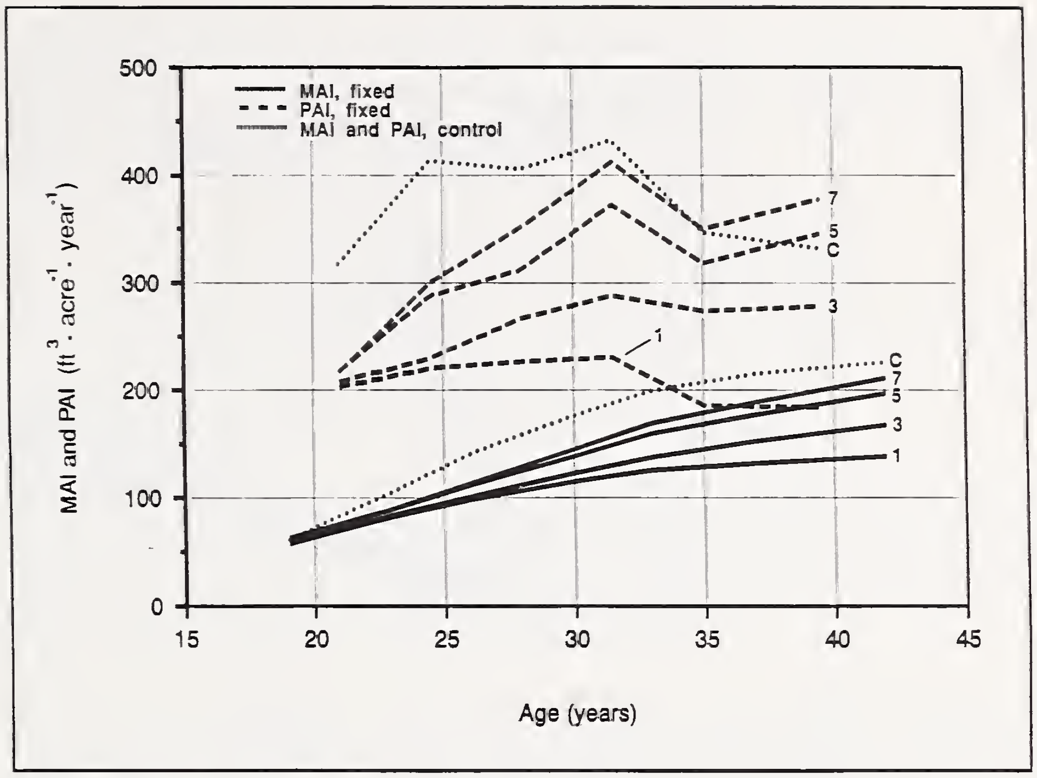


Figure 27—Mean annual increment and periodic annual increment in net volume (CVTS) in relation to age, fixed treatments and control.

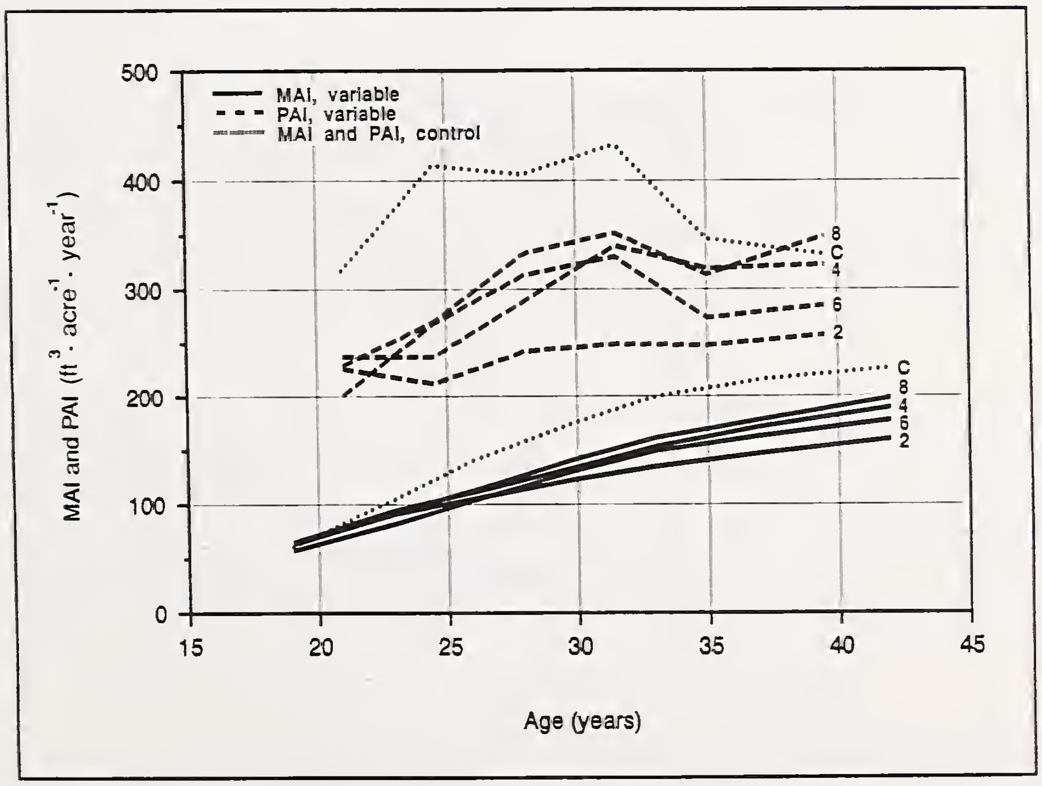


Figure 28—Mean annual increment and periodic annual increment in net volume (CVTS) in relation to age, variable treatments and control.

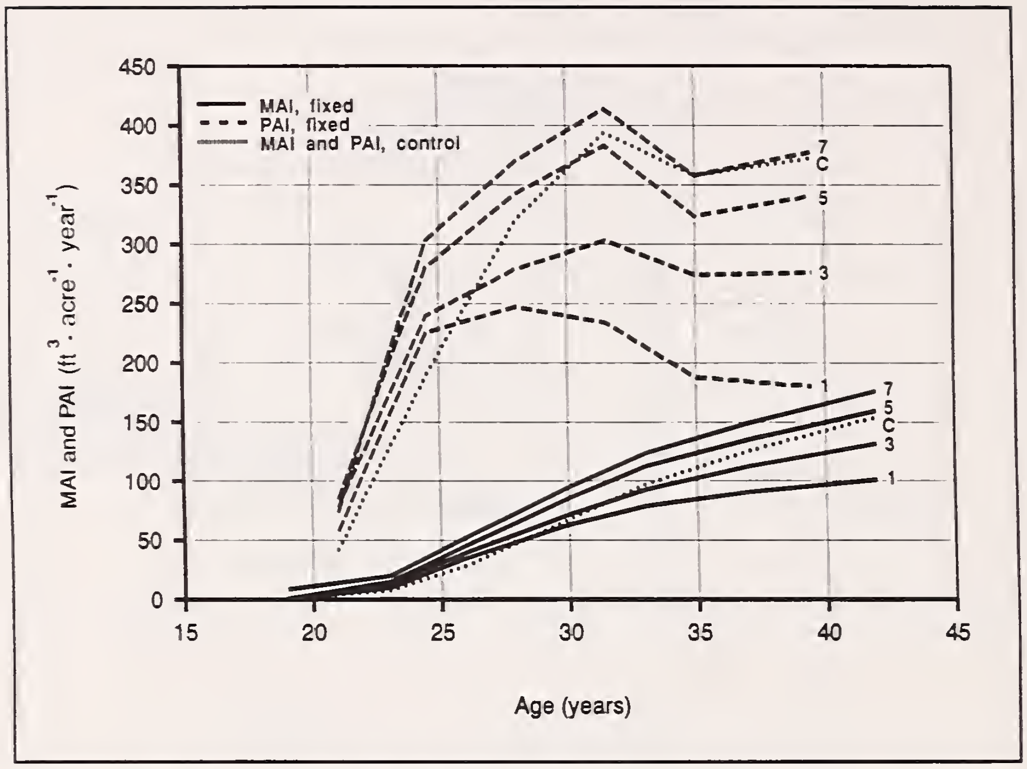


Figure 29—Mean annual increment and periodic annual increment in net mechantable volume (CV6) in relation to age, fixed treatments and control.

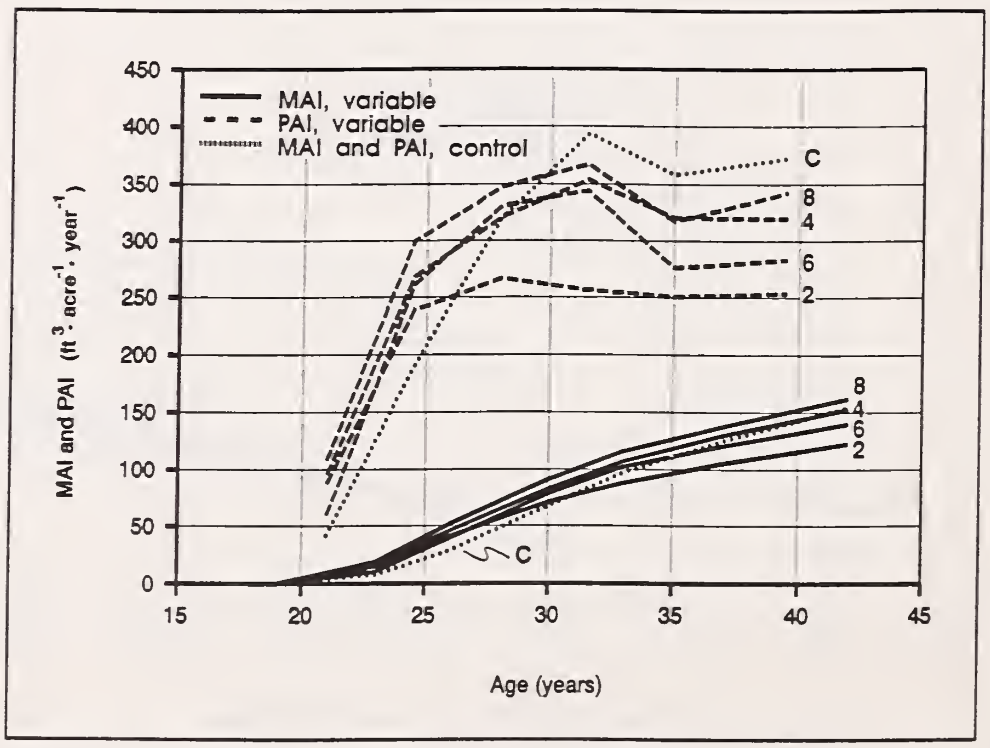


Figure 30—Mean annual increment and periodic annual increment in net merchantable volume (CV6) in relation to age, variable treatments and control.

## Growth Percents

Growth percentage is one method of expressing growth rates. The argument that one should seek maximum return on growing stock, one expression of which is growth percent, had an important place in the thinking that led to the LOGS study. Growth percents used here are calculated as,

$$\text{growth percent} = 100\left[\frac{PAI}{(X_1 + X_2)/2}\right]$$

where $X_1$ and $X_2$ are growing stock at beginning and end of the growth period.

Trends over time of growth percents for basal area of all trees, for CVTS, and for CV6 are shown in figures 31, 32, and 33 and in table 16.

**Basal area growth percent**—A consistent pattern has occurred, as expected, of growth percent declining over time. The higher density treatments have lower growth percents at a given age, because higher density means a larger divisor. The control falls much below the thinned treatments, both because of its larger divisor and because it has substantial suppression mortality.

**CVTS growth percent**—Patterns are similar but the spread between treatments is less, compared to basal area growth percent. Suppression mortality on the control represents proportionally much less volume than does basal area because of the small size of trees involved. In thinned treatments, although lower stocking reduces the divisor and is expected to result in higher growth percent, this is partially offset by the reduction in PAI associated with low stocking (further discussion below).

**CV6 growth percent**—The plots are in a stage of development where ratios of merchantable to total cubic volume are changing rapidly, and this has a considerable effect on the trends shown. Initial growth percents are very high because of the small values of CV6 used as the divisor. Ratios of merchantable volume to total volume increase faster on the lower stocked plots because of the larger trees; this tends to offset the relative increase in growth percent expected from lower total volume of growing stock. The net effect over the age range represented here is to reduce the differences in growth percent among treatments.

**Comparisons at age 42**—Growth percents in basal area, CVTS, and CV4 in relation to basal area stocking at age 42 (the most recent growth period available) are compared in figure 34. Volume growth percents are considerably higher than basal area growth percents, which in part represents the effect of rapid height growth. Growth percents in CV6 are somewhat higher than in CVTS and, at this stage in stand development, do not differ much among treatments. Because value increases with tree size, presumably value growth percents are higher than shown and might have somewhat different relations to level of growing stock and age.

## Crown Development

For the 1989 data (age 42), height to live crown (HLC) measurements were plotted over d.b.h., by treatment. With the possible exception of a few of the smallest trees, the relation was in all cases well represented by a horizontal line. Similar plots of live crown ratio (LCR) generally showed a positive slope, as would be expected, because total height increases with diameter. Therefore, although HLC treatment values can be expressed as simple means, LCR cannot. It seems reasonable to characterize treatment values of LCR by the LCR corresponding to average dimensions of the 40 largest (by d.b.h.) trees per acre. This is readily obtained as (H40-mean HLC)/H40.

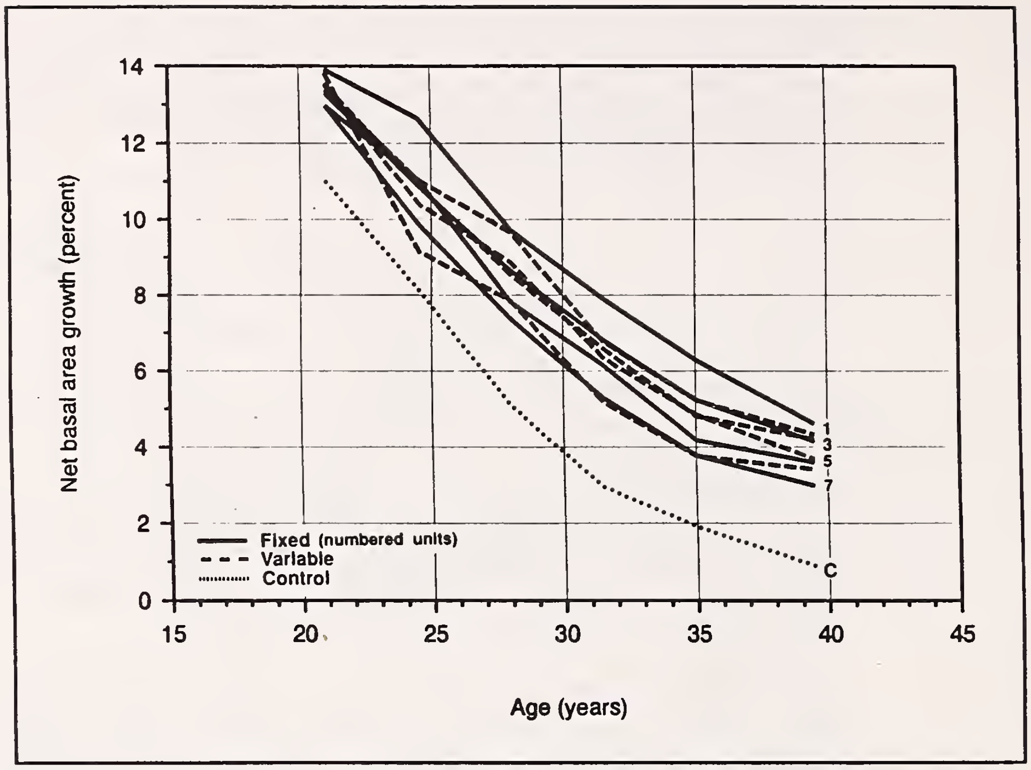


Figure 31—Net basal area growth percent in relation to age and treatment.

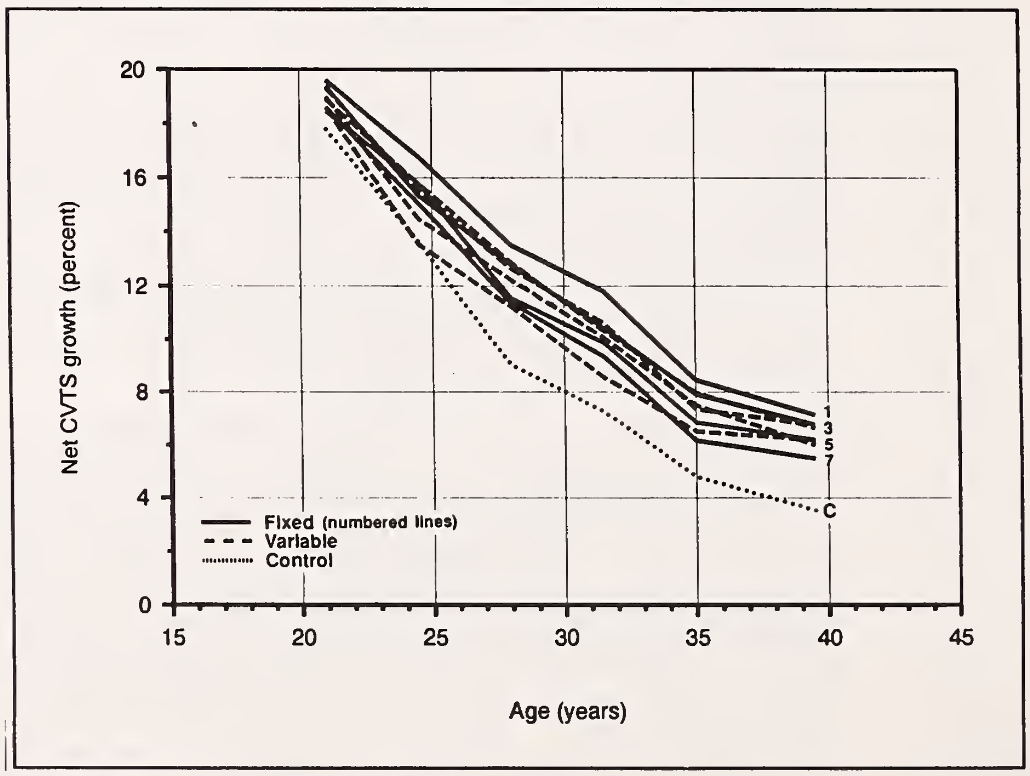


Figure 32—Net volume (CVTS) growth percent in relation to age and treatment.

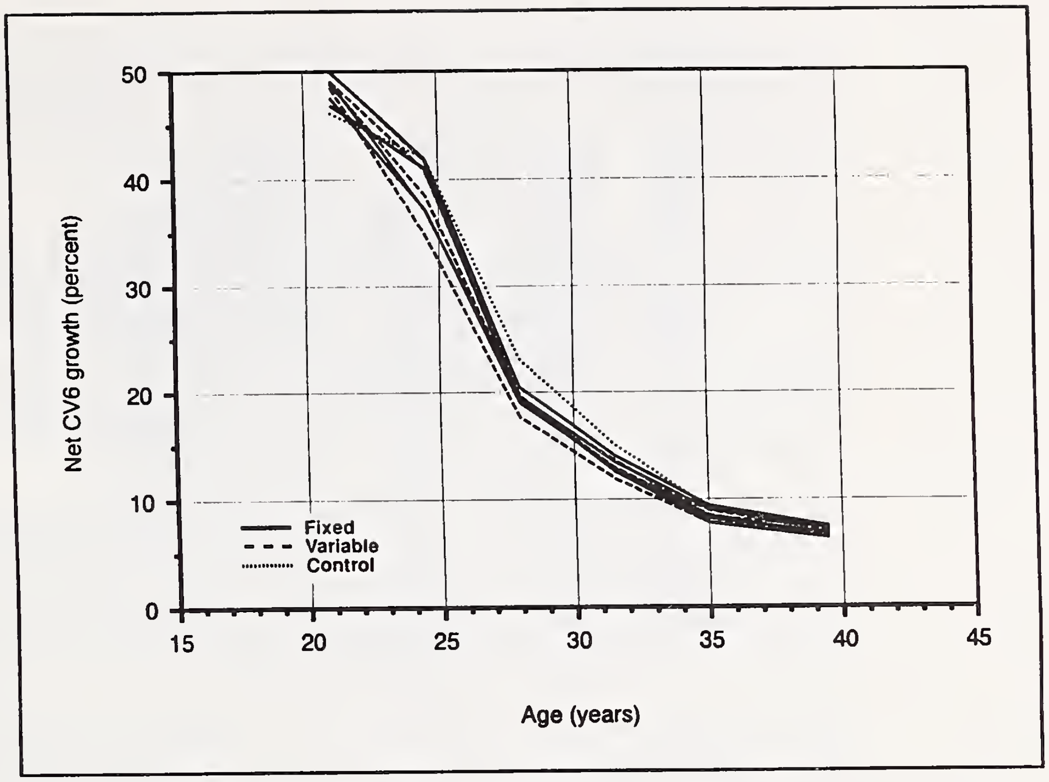


Figure 33—Net merchantable volume (CV6) growth percent in relation to age and treatment.

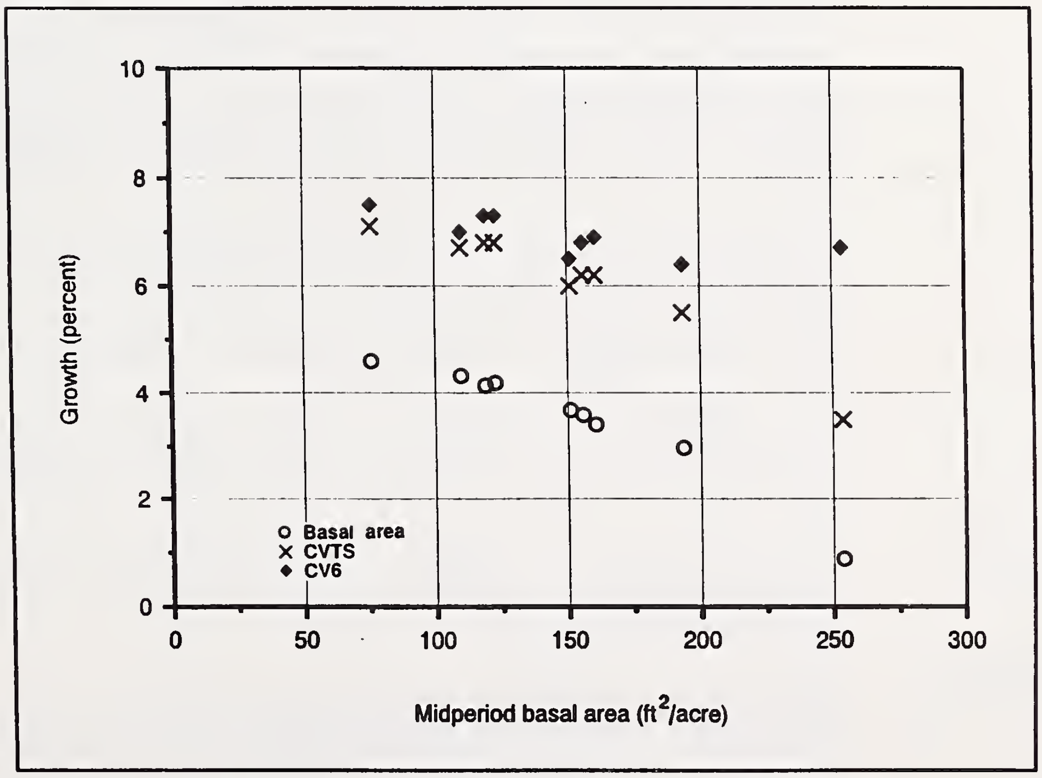


Figure 34—Comparison of growth percents in basal area, total volume, and merchantable volume in most recent growth period, 1984-89.

The resulting values at age 42 are shown in figure 35. Note that HLC values are almost identical for treatments 2, 3, and 6 and for treatments 7, 4, and 8. This corresponds to the expected equality of basal area at the end of the experiment, as shown in figure 3.

LCR40 values are strongly related to basal area (and, similarly, to RD), as shown in figure 36. A question not addressed in this report, but worthy of examination, is that of consistency of these relations over time and among installations.

Because total height within a treatment decreases with decreasing diameter, while HLC remains constant, the differences in live crown ratio associated with different stocking levels will be greater for smaller trees.

## Discussion

Results from the Iron Creek LOGS installation are qualitatively similar to those from other site II installations, as reported by Curtis and Marshall (report no. 8—1986) and Marshall and others (report no. 10—1992). Although there are some quantitative differences related to site and stand peculiarities, results generally are consistent with and reinforce conclusions previously drawn from other installations.

Two basic ideas played a major role in conception and design of the LOGS study. The first of these was a concept sometimes termed the "Langsaeter hypothesis" (Langsaeter 1941, as quoted by Braathe 1957; Staebler 1960), widely believed to have been demonstrated by European experience (Mar:Moller 1954) and stated in standard silviculture textbooks (for example, Smith 1962: 43). According to this hypothesis, the main effect of thinning, over a wide range of residual densities, is to redistribute a near-constant gross increment across various numbers of trees. If true, this would greatly simplify construction of yield tables and prediction of thinning effects. This hypothesis had never been tested, however, for young Douglas-fir and was still controversial in Europe in the late 1950s (Holmsgaard 1958).

A second related idea (Staebler 1959) was that, for financial efficiency, one should retain the minimum amount of growing stock feasible without major loss in growth. If the "Langsaeter hypothesis" is assumed to hold, then growth percent should be in direct inverse relation to growing stock over a considerable range in growing stock.

The LOGS study was designed to test these two concepts. It also includes a specific additional comparison among fixed, increasing, and decreasing trends in growing stock, and it was recognized that it would provide much concomitant information.

### Analysis of Variance

Results from the ANOVA were much the same as those previously reported for other LOGS installations and were consistent with the graphic comparisons of means that form most of this report.

### Growth-Growing Stock Relations

Except where specifically indicated, the discussion refers to net growth rather than gross growth. (For the various thinning treatments gross and net growth are almost identical; however, they differ considerably for the control, where suppression mortality has become important in the last two growth periods.)

Regressions for gross basal area growth in relation to midperiod basal area (fig. 37) show PAI increasing with stocking, although the curves become flatter with advancing age. The curves form a consistent series, with elevation decreasing uniformly with advancing age. Those for net basal area (fig. 38) show, from the third period on, an apparent maximum near the highest stocking in the thinned treatments. This maximum is due almost entirely to the effect of mortality on the control and would not appear were the control omitted.

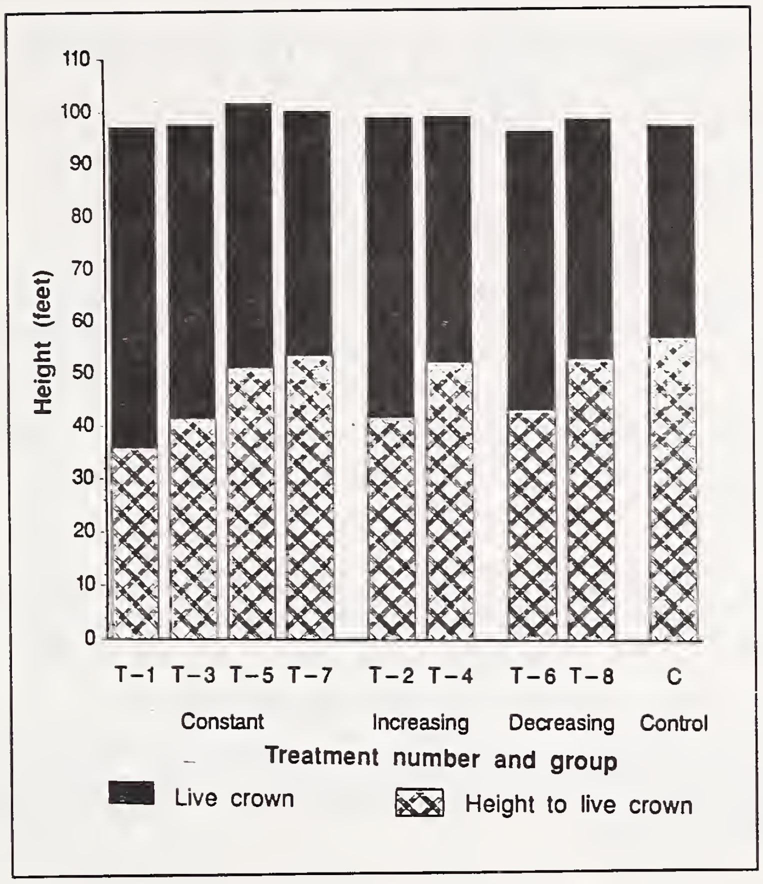


Figure 35—1989 heights and heights to live crown of 40 largest trees per acre, by treatment.

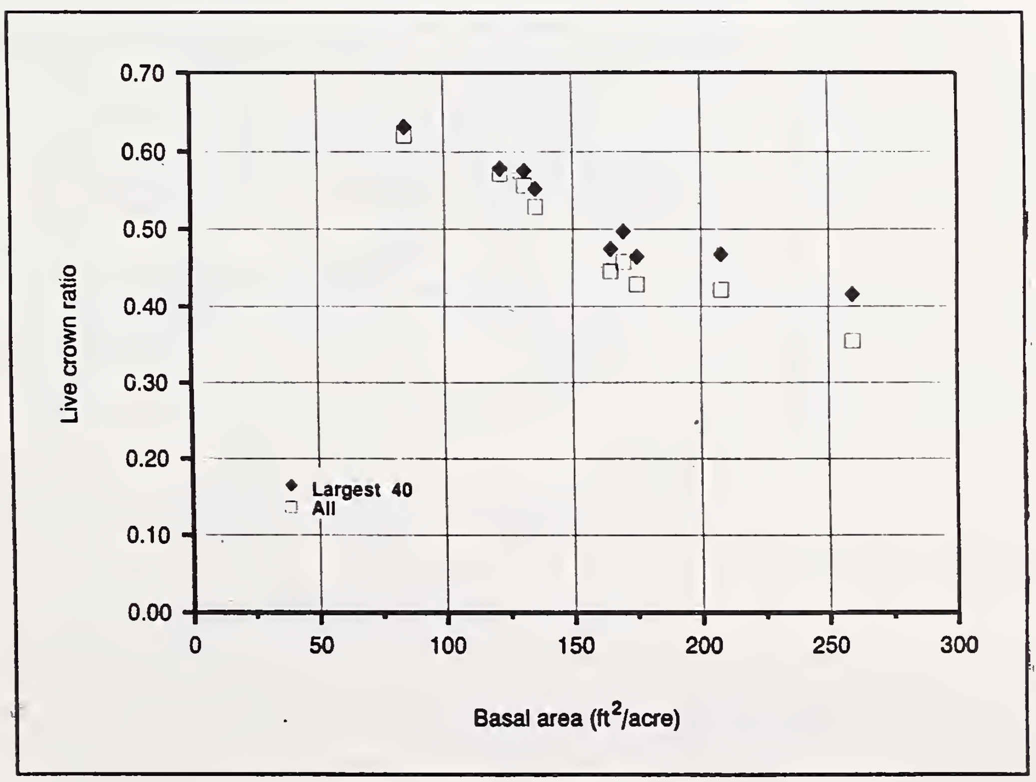


Figure 36—1989 (age 42) live crown ratios of largest 40 stems per acre and of all stems in relation to basal area.

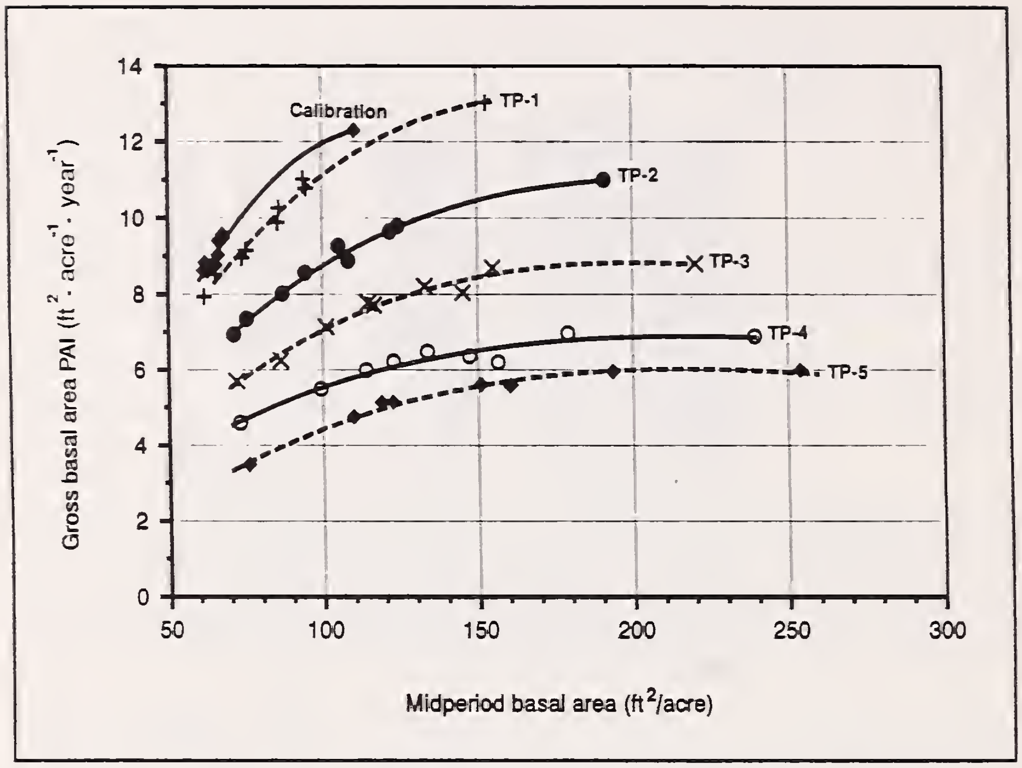


Figure 37—Gross basal area periodic annual increment in relation to midperiod basal area, by periods.

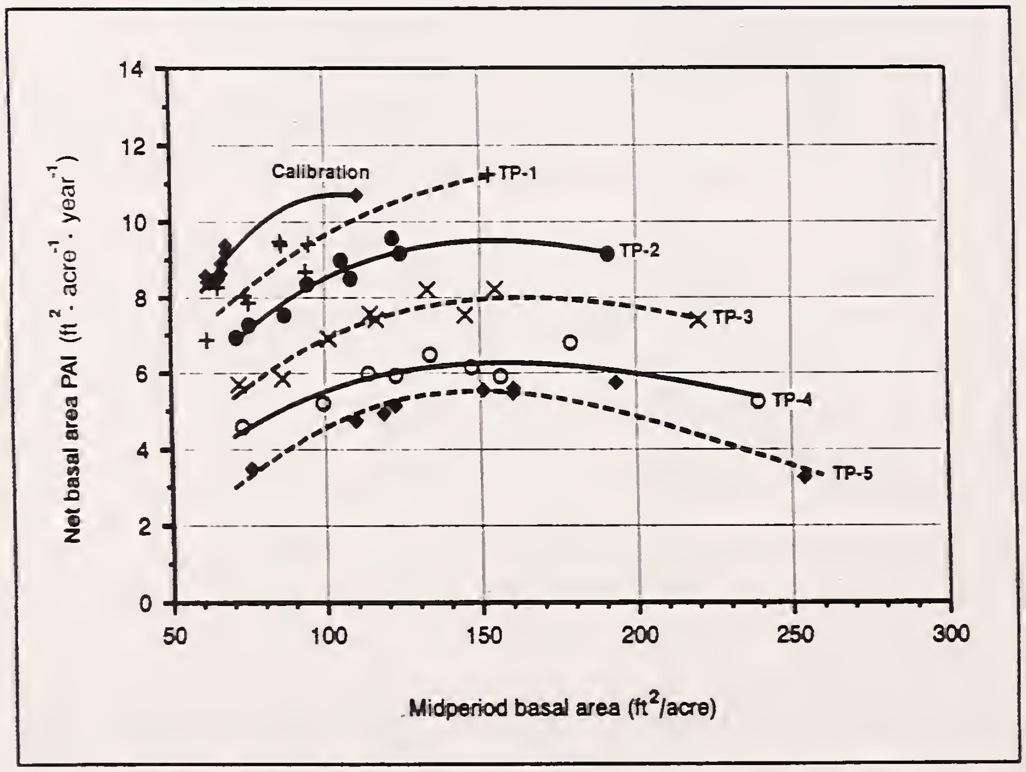


Figure 38—Net basal area periodic annual increment in relation to midperiod basal area, by periods.

Compared to the basal area increment regressions, similar regressions for gross and net CVTS PAI (figs. 39 and 40) have considerably steeper slopes, still present in the most recent period. This reflects rapid and continued height growth (report no. 8—Curtis and Marshall 1986: 80). No maximum is present for gross increment; for net, an apparent maximum occurs in the last two growth periods, arising entirely from mortality in the control.

Elevations decrease with advancing age, but the trend is somewhat irregular. This corresponds to irregularities in estimated height increments, which may or may not be real.

The corresponding net increment regressions for CV6 (fig. 41) strongly resemble the gross increment curves for CVTS. No maximum is present; mortality on the control is, so far, in small trees having little or no effect on the CV6 curve.

The above comparisons demonstrate that both net and gross volume increment are in fact **strongly related to growing stock**. The relation is considerably weaker for basal area increment; the difference is due to the height growth component of volume increment. Like other LOGS installations, Iron Creek clearly demonstrates that the "Langsaeter hypothesis" does not hold for young Douglas-fir stands making rapid height growth. The increased individual tree sizes and values associated with lower growing stock levels are bought at the cost of decreased total cubic volume production.

### Growth Percents

As expected, growth percents decline over time and with increasing stocking. Trends differ with the variable involved. Greatest differences between treatments occur with basal area growth percent (fig. 31). Differences are less for CVTS (fig. 32) and least for CV6 (fig. 33). Differences between basal area and CVTS growth percents arise because CVTS growth is more strongly related to stocking than is basal area growth; hence, a decrease in the denominator (midperiod CVTS) is associated with a decrease in the numerator (PAI) and reduces differences in growth percent. This is also true for CV6, but an additional factor involved is the small volume in CV6 present in small-diameter stands (higher density treatments).

A clear relation exists between growth percent in basal area and basal area, and between growth percent in CVTS and basal area stocking, but only a very weak one exists between growth percent in CV6 and basal area stocking (fig. 34). The latter relation is expected to become stronger as trees in all thinning treatments pass into diameter classes having most of their volume in CV6.

At age 42, growth percents in both CVTS and CV6 do not differ greatly among thinning treatments and are much higher than those in basal area (fig. 34). This again reflects the effect of rapid height increment and emphasizes the fact that basal area growth is not a surrogate for volume growth.

Although the general direction of the trends of growth percent in relation to growing stock is as expected, the magnitude of differences in volume growth percents among treatments is considerably less than anticipated when the study was established. Again, this is a consequence of failure of the "Langsaeter hypothesis."

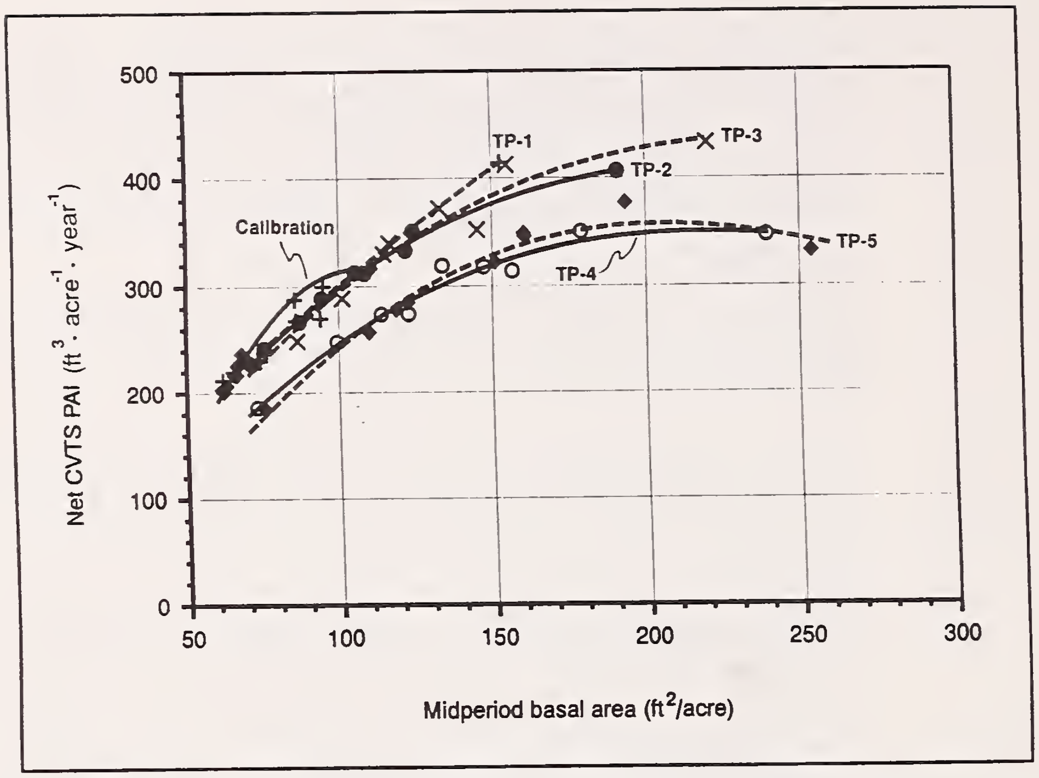


Figure 39—Periodic annual increment in net volume (CVTS) in relation to midperiod basal area, by periods.

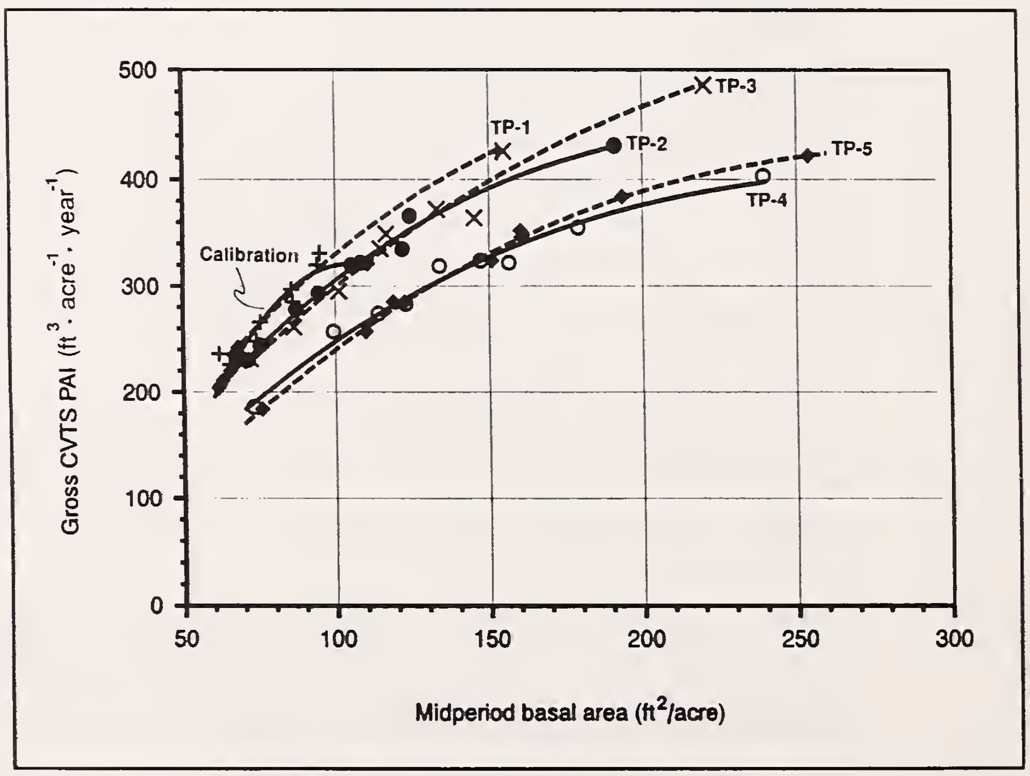


Figure 40—Periodic annual increment in gross volume (CVTS) in relation to midperiod basal area, by periods.

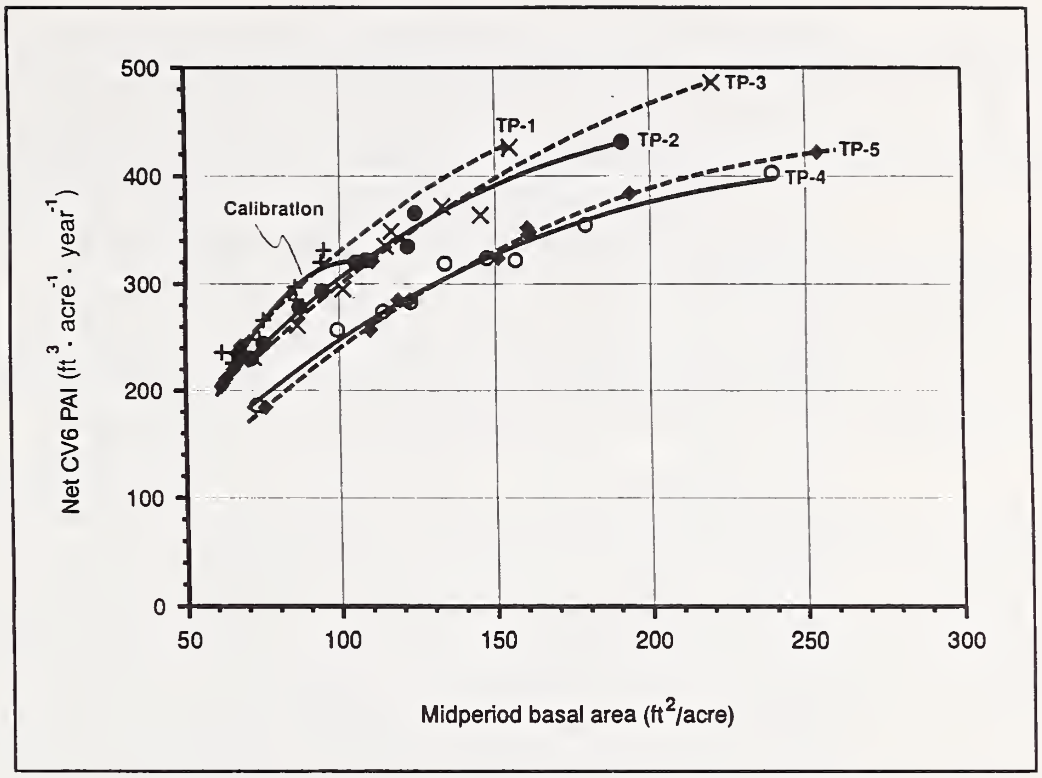


Figure 41—Periodic annual increment in net merchantable volume (CV6) in relation to midperiod basal area, by periods.

## Increasing vs. Fixed vs. Decreasing Treatments

The original plan called for comparison of increasing vs. fixed vs. decreasing treatments at each of two final basal area levels (see inside front cover). Namely, T-4 (increasing) vs. T-5 vs. T-8 (decreasing), and T-2 (increasing) vs. T-3 vs. T-6 (decreasing). In each group, the order of cumulative volume production (table 9) is decreasing > fixed > increasing, while that of attained QMD at the final measurement is the reverse.

The goal of equal final basal areas within each treatment group was not completely attained. Differences were not large—165 vs. 170 vs. 174 square feet per acre for the higher level, and 122 vs. 131 vs. 135 square feet per acre for the lower level group. But these differences were sufficient to cast some doubt on the reality of observed differences in volumes and diameters. The graphs of volume distribution by size classes (figs. 21, 22, and 23) do, however, strongly suggest that the increasing treatments have more volume and a larger fraction of their volume in the largest tree size class than do the fixed and decreasing treatments.

## Mean Annual Increment and Periodic Annual Increment

Mean annual increment (MAI) and PAI values in CVTS have been superimposed in figures 27 and 28, and those of MAI and PAI in CV6 in figures 29 and 30.

The jog in the PAI values for the period 1980-84 represents the second through the fifth growing seasons after the Mount St. Helens ashfall. It is tempting to consider this as a delayed effect (primarily on height increment) of the eruption; however, this is speculative and there could be quite a different cause.

The MAI and PAI curves shown bring out an important point, which is consistent with results to date from other LOGS installations and pertinent to current forest management controversies: at age 42, PAI is roughly twice MAI in total cubic volume (CVTS) and three times greater than MAI in merchantable volume (CV6) (tables 13, 17). All treatments are still far from culmination. It is clear that harvest at this age—not uncommon in the region today—would involve large losses in productivity relative to the potential.

## Stand Damage

Bear damage was striking when the Iron Creek installation was first established, but further damage was eliminated by fencing and little evidence of damage is visible today. Effect on the experiment has been negligible.

Root disease has had a considerable and increasing effect on stand development. In 1989, existing root rot pockets were mapped. One plot (plot 51 in treatment 1) had been virtually destroyed and was eliminated from analyses. Three plots (52, 91, 101) contained holes comprising less than 25 percent of the plot area. Two others (53 and 63) contained holes or scattered root rot trees not considered to have had much effect as yet. But because declining trees were removed in the frequent light thinnings, mortality and loss from this cause, as shown in the record, is considerably less than would have occurred under operational thinning on a longer cycle.

Except for loss of plot 51, the main effect of root rot on the experiment to date has been disruption of the initial choice of crop trees. Excluding plot 51, on which the loss was almost total, 13 percent of the initial crop trees had been replaced by substitutes by 1989. In most cases suitable substitutes were available, and the effect on stand growth has probably been minor.

A secondary effect of root disease is accelerated development of an understory of tolerant species—redcedar and hemlock. Plot 51 is a particularly striking example and now is occupied by dense and vigorous redcedar. Development here (and also at the Rocky Brook LOGS installation) suggests that root disease is often a major factor in natural conversion of initially homogeneous and nearly pure Douglas-fir stands to considerably less uniform stands with a substantial redcedar component.

The Mount St. Helens ashfall, though spectacular at the time, has had only a transitory effect.

## Volume Production

**Cumulative totals**—Cumulative net CVTS production to age 42 is still higher on the control than on any of the thinning treatments (fig. 18); although, with the onset of suppression mortality, the curves for the control and for treatment 7 appear to be converging. (When the LOGS study was planned, treatment 7 was designed as a treatment expected to do little more than forestall suppression-related mortality). In contrast, four treatments (5, 7, 6, and 8) exceed the control in cumulative net CV6 production (fig. 19). Treatment 1 ranks lowest in both CVTS and CV6.

**Volume distribution by tree size**—Figures 20 and 21 show distribution of total volume (CVTS) by tree size classes at age 42 and for cumulative production to age 42. From these it is clear that all thinning treatments except treatment 1 have produced substantially larger volumes than the control in the largest size classes, and that the proportions of volume in the larger size classes are much higher. This implies a considerably higher future value per cubic foot because of both lower logging cost and the much higher value of large trees, which are now moving into sizes where log grades will be changing rapidly.

At age 42, thinning treatments 5, 7, 6, and 8—the higher density treatments—appear to have produced the most favorable results in terms of the combination of relatively high CV6 and concentration of this volume on relatively large trees. Treatment 1 clearly has too few trees for a timber production objective and was in fact intended as an extreme treatment "designed to fail."

The LOGS study was not intended as a comparison of operationally feasible thinning regimes. It was designed as (1) a test of hypotheses on relations between growth and growing stock, and growth percent and growing stock, and (2) a means of developing information on the nature and quantitative values of growth-growing stock relations that would aid in predicting the results of possible thinning regimes. These aims have been met.

The very short thinning cycle used (10 feet of height growth = 3-5 years) is clearly impractical operationally. However, several studies have indicated that—within limits—thinning cycle has only a minor influence on production. Essentially the same results probably could have been achieved by initial precommercial thinning to the numbers left in the first treatment thinning, followed by one or two entries (rather than the five actually made) designed to give a similar trend in average growing stock over time.

## Future Uses of LOGS Study

This report summarizes the principal stand statistics for the Iron Creek installation to age 42 and represents completion of the study as originally planned. It also presents the principal analyses called for in the original study plan. This follows the pattern established by reports on other installations. There are a number of aspects not addressed, however, that should receive attention in the future.

**Continuation of installations**—Future development of these stands should be followed. Interpretation of the results and desirability of the stocking levels compared will be heavily influenced by the way they develop over the next few years. Early stocking levels that appeared relatively undesirable may change ranking with advancing age as densities, log grades, and values change. Further treatment is not feasible because of the relatively small plot sizes; there simply are too few trees left to allow reasonable thinning.

The members of the LOGS cooperative have agreed to continue remeasurement of these installations for at least 10 years after completion of the planned experiment.

**Value development**—To date, almost all analyses of LOGS installations (and all those presented for Iron Creek) have been in terms of volume and basal area rather than value production. This could be quite misleading, because value is strongly related to tree size. Interpretations could be very different and probably would be strongly influenced by choice of alternative harvest ages.

Iron Creek, and other LOGS installations, are now in a stage where values are changing rapidly. Further measurements soon will be available, and it should be possible, by using available simulators, to project present stand characteristics and size distributions for some distance into the future with a high degree of confidence.

Calculation and analyses of value development should provide much information on the value consequences of alternative growing stock levels and alternative harvest ages. These questions are highly pertinent to current controversies over forest management practices.

**Understory development**—To date, no quantitative descriptions or measurements have been made of the herbaceous vegetation, shrubs, and developing understory of hemlock and redcedar. Yet it is evident from casual inspection that strong relations exist among treatment, composition, and vigor of this secondary vegetation. At Iron Creek, the more heavily thinned treatments are developing a pronounced understory of hemlock and cedar that eventually will lead to a two-storied stand with distinctly different height and diameter distributions for Douglas-fir vs. the tolerant hemlock and cedar. Observation of other LOGS installations indicates that these relations differ markedly among sites. There is a need for examination and comparison of these relations across the various LOGS installations, for which long-term and very detailed records of development and treatment of the overstory are available. Again, these relations and differences are pertinent to current concerns about effects of thinning and stocking levels on development of wildlife habitat and biodiversity in young stands.

**Crown development**—Present crown dimensions and live crown ratios at Iron Creek (figs. 35, 36) are closely related to current basal area stocking (and to relative density). Crown measurements also exist for most of the past measurement dates at Iron Creek and for some of the other LOGS installations. An analysis of trends over time of crown dimensions in relation to tree dimensions, position, and stand density, and of the consistency of such relations across installations, would be highly desirable. Such information is an important component of a number of widely used stand development models, and good data are scarce.

## Metric Equivalents

1 inch = 2.54 centimeters

1 foot = 0.3048 meter

1 square foot = 0.09290 square meter

1 cubic foot = 0.028 cubic meter

1 acre = 0.4047 hectare

1 square foot per acre = 0.2296 square meter per hectare

1 cubic foot per acre = 0.06997 cubic meter per hectare

1 mile = 1.609 kilometers

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## Appendix 1: Description of Experiment

The following information is excerpted (and paraphrased) from Williamson and Staebler (report no. 1—1971).

The experiment is designed to test a number of thinning regimes beginning in young stands made alike at the start through a calibration thinning. Thereafter, through the time required for 60 feet of height growth, growing stock is controlled by allowing a specified addition to the growing stock between successive thinnings. Any extra growth is cut and is one of the measured effects of the thinning regime.

### Experimental Design

A single experiment consists of eight thinning regimes plus unthinned plots whose growth is the basis for treatment in these regimes. There are three plots per treatment arranged in a completely randomized design for a total of 27 plots of one-fifth acre each.

### Crop Tree Selection

Well-formed, uniformly spaced, dominant trees at the rate of 80 per acre, or 16 per plot, are designated as crop trees before initial thinning. Each quarter of a plot must have no fewer than three suitable crop trees or no more than five—another criterion for stand uniformity.

### Initial or "Calibration" Thinning

All 24 treated plots are thinned initially to the same density to minimize the effect of variations in original density on stand growth. Density of residual trees is controlled by quadratic mean diameter (diameter of tree of average basal area) of the residual stand according to the formula,

$$\text{Average spacing in feet} = (0.6167 \times \text{QMD}) + 8 .$$

If one concentrates on leaving a certain amount of basal area corresponding to an estimated overall quadratic mean d.b.h. ...[QMD], then the residual number of trees may vary freely and the actual...[QMDs] may differ among plots...plus or minus 10 percent. Alternatively, if emphasis is on leaving a certain number of trees to correspond to an estimated overall...[QMD], then the basal areas differ among plots and the actual...[QMDs] may vary...plus or minus 15 percent between plots.

### Treatments

The eight tested thinning regimes differ in the amount of basal area allowed to accumulate in the growing stock. The amount of growth retained in any thinning is a predetermined percentage of the gross increase found in the unthinned plots since the last thinning...(table inside front cover). The average residual basal area for all thinned plots after the calibration thinning is the foundation upon which all future growing stock accumulation is based. As used in the study, control plots may be thought of as providing a "local gross yield table" for the study area.

### Control of Thinning Interval

Thinnings will be made (after the calibration thinning) whenever average height growth of crop trees...comes closest to each multiple of 10 feet [above the initial height].

### Control of Type of Thinning

As far as possible, type of thinning is eliminated as a variable in the treatment thinnings through several specifications.

1. No crop tree may be cut until all noncrop trees have been cut (another tree may be substituted for a crop tree damaged by logging or killed by natural agents).

2. The quadratic mean diameter of cut trees should approximate that of trees available for cutting.

3. The diameters of cut trees should be distributed across the full diameter range of trees available for cutting.

## Appendix 2: Tables

**Table 1—Analysis of variance**

| Source of variation | Degrees of freedom (5 treatment periods) |
|---|---|
| Treatments: | (7) |
| A. Fixed vs. variable percentage treatments | 1 |
| B. Among levels of fixed percentage treatments— | |
| Linear effects | 1 |
| Quadratic effects | 1 |
| Cubic effects | 1 |
| C. Increasing percentage treatments | 1 |
| D. Between levels of increasing percentage treatments | 1 |
| E. Between levels of decreasing percentage treatments | 1 |
| Error a for testing treatments | 15 |
| P periods | 4 |
| Treatments x period interactions: | |
| P x A | 4 |
| P x B linear effects | 4 |
| P x B quadratic effects | 4 |
| P x B cubic effects | 4 |
| P x C | 4 |
| P x D | 4 |
| P x E | 4 |
| Error b for testing interactions | 60 |
| Total | 115 |

**Table 2—Analysis of variance results for periodic annual gross growth and gross growth percent in volume (CVTS) and basal area, and net periodic annual growth in quadratic mean diameter**

| | P-values[a] and mean square errors | | | | |
|---|---|---|---|---|---|
| | Volume | | Basal area | | Diameter |
| Source of variation | PAI | Growth % | PAI | Growth % | PAI |
| Treatments: | 0.00** | 0.00** | 0.00** | 0.00** | 0.00** |
| A. Fixed vs. variable | .66 | .38 | .29 | .96 | .83 |
| B. Fixed (linear) | .00** | .00** | .00** | .00** | .00** |
| B. Fixed (quadratic) | .14 | .33 | .17 | .13 | .37 |
| B. Fixed (cubic) | .85 | .20 | .71 | .41 | .60 |
| C. Increasing vs. decreasing | .00** | .00** | .00** | .00** | .00** |
| D. Between increasing | .00** | .00** | .00** | .00** | .07 |
| E. Between decreasing | .00** | .00** | .16 | .00** | .05 |
| Error a mean square | 841.39 | .290 | .423 | .190 | .00244 |
| P periods: | .00** | .00** | .00** | .00** | .00** |
| P x A | .66 | .74 | .41 | .07 | .37 |
| P x B (linear) | .00** | .10 | .08 | .00** | .00** |
| P x B (quadratic) | .05* | .52 | .00** | .04* | .50 |
| P x B (cubic) | .77 | .76 | .22 | .70 | .52 |
| P x C | .02* | .26 | .00** | .00** | .04* |
| P x D | .06 | .41 | .26 | .99 | .06 |
| P x E | .13 | .17 | .12 | .00** | .15 |
| Error b mean square | 290.72 | .310 | .0668 | .0376 | .000301 |

[a] P is the probability of a larger F, given that the null hypothesis of no difference among means is true. Significance levels: * = 0.01<p<0.05; ** = 0.00<p<0.01.

**Table 3a—Treatment mean heights (H40) of 40 largest diameter trees per acre and of crop trees (Hcrop) by treatment, period, and year**

| Treatment | After cut | Before cut | | | | | |
|---|---|---|---|---|---|---|---|
| | 1966 (19)[a] | 1970 (23) | 1973 (26) | 1977 (30) | 1980 (33) | 1984 (37) | 1989 (42) |
| | | | | *Feet* | | | |
| Fixed: | | | | | | | |
| 1[b] H40 | 39.9 | 50.1 | 59.0 | 68.9 | 78.7 | 85.3 | 97.3 |
| Hcrop | 35.2 | 46.0 | 53.3 | 64.0 | 72.9 | 81.0 | 94.4 |
| 3 H40 | 37.3 | 49.1 | 56.4 | 67.6 | 75.5 | 84.4 | 97.8 |
| Hcrop | 35.2 | 46.8 | 54.4 | 65.0 | 73.2 | 82.1 | 94.8 |
| 5 H40 | 38.4 | 50.3 | 59.4 | 69.7 | 78.3 | 87.8 | 102.0 |
| Hcrop | 37.0 | 48.7 | 57.6 | 67.8 | 76.9 | 85.5 | 98.5 |
| 7 H40 | 38.5 | 49.3 | 58.6 | 69.9 | 78.5 | 87.8 | 100.6 |
| Hcrop | 36.3 | 47.1 | 55.8 | 66.8 | 75.9 | 84.4 | 96.4 |
| Increasing: | | | | | | | |
| 2 H40 | 40.1 | 50.7 | 57.8 | 67.3 | 75.7 | 85.5 | 99.4 |
| Hcrop | 38.2 | 48.9 | 57.3 | 66.4 | 74.6 | 83.7 | 95.3 |
| 4 H40 | 40.8 | 52.8 | 59.6 | 68.6 | 77.5 | 87.4 | 99.7 |
| Hcrop | 39.4 | 50.4 | 57.8 | 67.3 | 76.3 | 85.6 | 96.9 |
| Decreasing: | | | | | | | |
| 6 H40 | 36.9 | 47.6 | 55.7 | 67.2 | 75.3 | 83.7 | 96.9 |
| Hcrop | 35.6 | 46.1 | 53.8 | 64.6 | 73.2 | 82.2 | 94.3 |
| 8 H40 | 40.4 | 51.0 | 60.0 | 69.0 | 79.2 | 85.8 | 99.2 |
| Hcrop | 38.4 | 48.8 | 57.4 | 66.4 | 79.2 | 83.4 | 96.6 |
| Unthinned: | | | | | | | |
| C H40 | 36.6 | 48.5 | 57.1 | 67.7 | 76.5 | 85.9 | 98.1 |
| Hcrop | 35.4 | 46.9 | 55.6 | 65.4 | 74.7 | 83.5 | 95.3 |

[a] Stand age in parentheses.

[b] Plot 51 omitted from mean of treatment 1 because of root rot.

**Table 3b—Treatment mean heights (H40) of 100 largest diameter trees per hectare and of crop trees, by treatment, period, and year**

| Treatment | After cut | Before cut | | | | | |
|---|---|---|---|---|---|---|---|
| | 1966 (19)[a] | 1970 (23) | 1973 (26) | 1977 (30) | 1980 (33) | 1984 (37) | 1989 (42) |
| | *Meters* | | | | | | |
| Fixed: | | | | | | | |
| 1[b] H40 | 12.2 | 15.3 | 18.0 | 21.0 | 24.0 | 26.0 | 29.6 |
| Hcrop | 10.7 | 14.0 | 16.2 | 19.5 | 22.2 | 24.7 | 28.8 |
| 3 H40 | 11.4 | 15.0 | 17.2 | 20.6 | 23.0 | 25.7 | 29.8 |
| Hcrop | 10.7 | 14.3 | 16.6 | 19.8 | 22.3 | 25.0 | 28.9 |
| 5 H40 | 11.7 | 15.3 | 18.1 | 21.2 | 23.9 | 26.8 | 31.1 |
| Hcrop | 11.3 | 14.8 | 17.6 | 20.7 | 23.4 | 26.1 | 30.0 |
| 7 H40 | 11.7 | 15.0 | 17.9 | 21.3 | 23.9 | 26.8 | 30.7 |
| Hcrop | 11.1 | 14.4 | 17.0 | 20.4 | 23.1 | 25.7 | 29.4 |
| Increasing: | | | | | | | |
| 2 H40 | 12.2 | 15.5 | 17.6 | 20.5 | 23.1 | 26.1 | 30.3 |
| Hcrop | 11.6 | 14.9 | 17.5 | 20.2 | 22.7 | 25.5 | 29.0 |
| 4 H40 | 12.4 | 16.1 | 18.2 | 20.9 | 23.6 | 26.6 | 30.4 |
| Hcrop | 12.0 | 15.4 | 17.6 | 20.5 | 23.3 | 26.1 | 29.5 |
| Decreasing: | | | | | | | |
| 6 H40 | 11.2 | 14.5 | 17.0 | 20.5 | 22.9 | 25.5 | 29.5 |
| Hcrop | 10.8 | 14.0 | 16.4 | 19.7 | 22.3 | 25.1 | 28.8 |
| 8 H40 | 12.3 | 15.6 | 18.3 | 21.0 | 24.1 | 26.2 | 30.2 |
| Hcrop | 11.7 | 14.9 | 17.5 | 20.2 | 24.1 | 25.4 | 29.4 |
| Unthinned: | | | | | | | |
| C H40 | 11.1 | 14.8 | 17.4 | 20.6 | 23.3 | 26.2 | 29.9 |
| Hcrop | 10.8 | 14.3 | 17.0 | 19.9 | 22.8 | 25.5 | 29.0 |

[a] Stand age in parentheses.

[b] Plot 51 omitted from mean of treatment 1 because of root rot.

**Table 4a—Number of trees per acre by treatment, plot, period, year and age**

| Treatment | Plot | Calibration | | Period 1 | | Period 2 | | Period 3 | | Period 4 | | Period 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | After cut 1966 (19)[a] | Before cut 1970 (23) | After cut 1970 (23) | Before cut 1973 (26) | After cut 1973 (26) | Before cut 1977 (30) | After cut 1977 (30) | Before cut 1980 (33) | After cut 1980 (33) | Before cut 1984 (37) | After cut 1984 (37) | 1989 (42) |
| | | – – – – – – – – – – – | – – – – – – | – – – – | – – – – | – – – – | – – – – | Number of Trees – – | – – – – | – – – – | – – – – | – – – – | – – – – |
| Fixed: | | | | | | | | | | | | | |
| 1[b] | 21 | 350 | 345 | 205 | 205 | 140 | 140 | 95 | 95 | 75 | 75 | 55 | 55 |
| | 33 | 360 | 355 | 225 | 215 | 155 | 150 | 110 | 110 | 80 | 80 | 65 | 65 |
| | 51 | 355 | 330 | 240 | 210 | 160 | 145 | 95 | 85 | 75 | 75 | 65 | 65 |
| 3 | 31 | 355 | 350 | 275 | 270 | 225 | 220 | 185 | 185 | 160 | 160 | 135 | 135 |
| | 42 | 335 | 335 | 215 | 210 | 165 | 165 | 145 | 145 | 125 | 125 | 100 | 100 |
| | 52 | 355 | 335 | 255 | 230 | 190 | 180 | 155 | 150 | 150 | 150 | 110 | 105 |
| 5 | 12 | 345 | 335 | 275 | 275 | 230 | 230 | 215 | 215 | 195 | 195 | 165 | 165 |
| | 41 | 335 | 330 | 255 | 255 | 220 | 220 | 205 | 205 | 185 | 185 | 160 | 160 |
| | 72 | 360 | 350 | 300 | 290 | 275 | 260 | 260 | 260 | 250 | 240 | 210 | 210 |
| 7 | 11 | 345 | 340 | 305 | 305 | 280 | 280 | 280 | 280 | 265 | 265 | 235 | 230 |
| | 23 | 355 | 345 | 340 | 335 | 325 | 310 | 310 | 310 | 305 | 300 | 270 | 270 |
| | 63 | 380 | 355 | 355 | 310 | 310 | 300 | 300 | 290 | 290 | 285 | 275 | 265 |
| Increasing: | | | | | | | | | | | | | |
| 2 | 82 | 360 | 355 | 200 | 195 | 150 | 150 | 125 | 125 | 110 | 110 | 95 | 95 |
| | 91 | 370 | 350 | 215 | 190 | 175 | 175 | 135 | 130 | 130 | 130 | 110 | 110 |
| | 101 | 350 | 335 | 180 | 180 | 140 | 135 | 120 | 120 | 105 | 100 | 85 | 85 |
| 4 | 13 | 335 | 330 | 200 | 190 | 155 | 155 | 150 | 145 | 140 | 140 | 130 | 130 |
| | 62 | 400 | 390 | 285 | 265 | 235 | 230 | 215 | 215 | 190 | 190 | 180 | 175 |
| | 111 | 355 | 345 | 245 | 230 | 200 | 190 | 175 | 175 | 165 | 165 | 150 | 150 |
| Decreasing: | | | | | | | | | | | | | |
| 6 | 15 | 350 | 335 | 290 | 285 | 240 | 235 | 205 | 200 | 170 | 165 | 130 | 130 |
| | 43 | 370 | 350 | 315 | 290 | 255 | 250 | 195 | 195 | 170 | 170 | 130 | 130 |
| | 81 | 360 | 345 | 315 | 310 | 260 | 255 | 210 | 210 | 175 | 175 | 125 | 125 |
| 8 | 14 | 340 | 330 | 290 | 290 | 245 | 245 | 225 | 220 | 195 | 190 | 150 | 150 |
| | 53 | 360 | 350 | 345 | 315 | 310 | 305 | 285 | 275 | 270 | 265 | 230 | 225 |
| | 73 | 355 | 355 | 305 | 270 | 270 | 270 | 260 | 255 | 210 | 210 | 180 | 180 |
| Unthinned: | | | | | | | | | | | | | |
| C | 22 | 1345 | 1390 | 1390 | 1325 | 1325 | 1260 | 1260 | 1180 | 1180 | 1105 | 1105 | 920 |
| | 25 | 1385 | 1400 | 1400 | 1395 | 1395 | 1320 | 1320 | 1180 | 1180 | 1035 | 1035 | 830 |
| | 71 | 1085 | 1140 | 1140 | 1160 | 1160 | 1110 | 1110 | 1025 | 1025 | 890 | 890 | 785 |

[a] Stand age in parentheses.

[b] Plot 51 abandoned 1989 because of severe root rot.

**Table 4b—Number of trees per hectare by treatment, plot, period, year and age**

| | | Calibration | | Period 1 | | Period 2 | | Period 3 | | Period 4 | | Period 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | Plot | After cut 1966 (19)[a] | Before cut 1970 (23) | After cut 1970 (23) | Before cut 1973 (26) | After cut 1973 (26) | Before cut 1977 (30) | After cut 1977 (30) | Before cut 1980 (33) | After cut 1980 (33) | Before cut 1984 (37) | After cut 1984 (37) | 1989 (42) |
| | | Number of Trees | | | | | | | | | | | |
| Fixed: | | | | | | | | | | | | | |
| 1[b] | 21 | 865 | 853 | 507 | 507 | 346 | 346 | 235 | 235 | 185 | 185 | 136 | 136 |
| | 33 | 890 | 877 | 556 | 531 | 383 | 371 | 272 | 272 | 198 | 198 | 161 | 161 |
| | 51 | 877 | 815 | 593 | 519 | 395 | 358 | 235 | 210 | 185 | 185 | 161 | 161 |
| 3 | 31 | 877 | 865 | 680 | 667 | 556 | 544 | 457 | 457 | 395 | 395 | 334 | 334 |
| | 42 | 828 | 828 | 531 | 519 | 408 | 408 | 358 | 358 | 309 | 309 | 247 | 247 |
| | 52 | 877 | 828 | 630 | 568 | 469 | 445 | 383 | 371 | 371 | 371 | 272 | 259 |
| 5 | 12 | 853 | 828 | 680 | 680 | 568 | 568 | 531 | 531 | 482 | 482 | 408 | 408 |
| | 41 | 828 | 815 | 630 | 630 | 544 | 544 | 507 | 507 | 457 | 457 | 395 | 395 |
| | 72 | 890 | 865 | 741 | 717 | 680 | 642 | 642 | 642 | 618 | 593 | 519 | 519 |
| 7 | 11 | 853 | 840 | 754 | 754 | 692 | 692 | 692 | 692 | 655 | 655 | 581 | 568 |
| | 23 | 877 | 853 | 840 | 828 | 803 | 766 | 766 | 766 | 754 | 741 | 667 | 667 |
| | 63 | 939 | 877 | 877 | 766 | 766 | 741 | 741 | 717 | 717 | 704 | 680 | 655 |
| Increasing: | | | | | | | | | | | | | |
| 2 | 82 | 890 | 877 | 494 | 482 | 371 | 371 | 309 | 309 | 272 | 272 | 235 | 235 |
| | 91 | 914 | 865 | 531 | 469 | 432 | 432 | 334 | 321 | 321 | 321 | 272 | 272 |
| | 101 | 865 | 828 | 445 | 445 | 346 | 334 | 297 | 297 | 259 | 247 | 210 | 210 |
| 4 | 13 | 828 | 815 | 494 | 469 | 383 | 383 | 371 | 358 | 346 | 346 | 321 | 321 |
| | 62 | 988 | 964 | 704 | 655 | 581 | 568 | 531 | 531 | 469 | 469 | 445 | 432 |
| | 111 | 877 | 853 | 605 | 568 | 494 | 469 | 432 | 432 | 408 | 408 | 371 | 371 |
| Decreasing: | | | | | | | | | | | | | |
| 6 | 15 | 865 | 828 | 717 | 704 | 593 | 581 | 507 | 494 | 420 | 408 | 321 | 321 |
| | 43 | 914 | 865 | 778 | 717 | 630 | 618 | 482 | 482 | 420 | 420 | 321 | 321 |
| | 81 | 890 | 853 | 778 | 766 | 642 | 630 | 519 | 519 | 432 | 432 | 309 | 309 |
| 8 | 14 | 840 | 815 | 717 | 717 | 605 | 605 | 556 | 544 | 482 | 469 | 371 | 371 |
| | 53 | 890 | 865 | 853 | 778 | 766 | 754 | 704 | 680 | 667 | 655 | 568 | 556 |
| | 73 | 877 | 877 | 754 | 667 | 667 | 667 | 642 | 630 | 519 | 519 | 445 | 445 |
| Unthinned: | | | | | | | | | | | | | |
| C | 22 | 3324 | 3435 | 3435 | 3274 | 3274 | 3114 | 3114 | 2916 | 2916 | 2731 | 2731 | 2273 |
| | 25 | 3422 | 3459 | 3459 | 3447 | 3447 | 3262 | 3262 | 2916 | 2916 | 2558 | 2558 | 2051 |
| | 71 | 2681 | 2817 | 2817 | 2866 | 2866 | 2743 | 2743 | 2533 | 2533 | 2199 | 2199 | 1940 |

[a] Stand age in parentheses.

[b] Plot 51 abandoned 1989 because of severe root rot.

**Table 5a—Basal area per acre by treatment, plot, period, year and age**

| Treatment | Plot | Calibration | | Period 1 | | Period 2 | | Period 3 | | Period 4 | | Period 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | After cut 1966 (19)[a] | Before cut 1970 (23) | After cut 1970 (23) | Before cut 1973 (26) | After cut 1973 (26) | Before cut 1977 (30) | After cut 1977 (30) | Before cut 1980 (33) | After cut 1980 (33) | Before cut 1984 (37) | After cut 1984 (37) | 1989 (42) |
| | | *Square feet* | | | | | | | | | | | |
| Fixed: | | | | | | | | | | | | | |
| 1[b] | 21 | 45.0 | 78.1 | 52.9 | 77.7 | 57.8 | 85.4 | 62.5 | 79.2 | 64.6 | 83.3 | 65.9 | 82.2 |
| | 33 | 44.0 | 79.5 | 53.1 | 77.9 | 57.1 | 84.9 | 64.5 | 82.0 | 63.0 | 81.0 | 68.0 | 86.6 |
| | 51 | 41.3 | 70.5 | 52.8 | 69.8 | 56.5 | 77.9 | 55.8 | 63.0 | 59.1 | 74.5 | 67.7 | 85.6 |
| 3 | 31 | 43.9 | 75.0 | 61.9 | 87.1 | 73.9 | 105.8 | 92.6 | 115.2 | 100.4 | 125.3 | 110.5 | 136.4 |
| | 42 | 51.0 | 88.7 | 62.2 | 86.8 | 69.3 | 100.6 | 92.9 | 114.5 | 100.6 | 122.0 | 104.6 | 129.5 |
| | 52 | 43.9 | 75.9 | 61.6 | 84.2 | 72.8 | 100.0 | 86.7 | 104.7 | 104.7 | 130.2 | 104.4 | 127.6 |
| 5 | 12 | 48.2 | 82.5 | 71.4 | 101.6 | 92.3 | 129.1 | 122.1 | 147.5 | 134.2 | 160.0 | 141.1 | 169.2 |
| | 41 | 51.1 | 85.8 | 71.3 | 102.3 | 91.0 | 128.7 | 121.9 | 148.3 | 135.1 | 161.5 | 142.2 | 171.1 |
| | 72 | 46.5 | 79.4 | 71.3 | 95.3 | 90.6 | 118.1 | 118.1 | 140.2 | 135.4 | 157.0 | 141.8 | 168.6 |
| 7 | 11 | 52.2 | 88.5 | 81.3 | 114.6 | 107.6 | 147.3 | 147.3 | 173.1 | 169.4 | 198.9 | 179.5 | 209.1 |
| | 23 | 46.8 | 81.3 | 79.5 | 109.6 | 107.5 | 144.0 | 144.0 | 170.5 | 169.1 | 195.1 | 179.5 | 208.6 |
| | 63 | 48.7 | 81.4 | 81.4 | 102.7 | 102.7 | 136.4 | 136.4 | 158.1 | 158.1 | 183.8 | 178.6 | 206.0 |
| Increasing: | | | | | | | | | | | | | |
| 2 | 82 | 49.3 | 88.1 | 52.5 | 74.5 | 60.0 | 89.1 | 77.9 | 97.2 | 88.3 | 109.7 | 99.2 | 123.3 |
| | 91 | 45.0 | 77.2 | 51.2 | 67.1 | 61.7 | 92.8 | 74.5 | 89.2 | 89.2 | 112.4 | 98.7 | 123.5 |
| | 101 | 52.1 | 88.0 | 51.1 | 75.0 | 60.7 | 87.7 | 80.2 | 98.9 | 89.2 | 107.1 | 95.8 | 118.1 |
| 4 | 13 | 51.7 | 90.6 | 61.8 | 85.4 | 74.6 | 108.4 | 106.0 | 125.5 | 123.0 | 147.3 | 135.9 | 163.6 |
| | 62 | 47.2 | 83.5 | 64.8 | 90.0 | 82.1 | 115.9 | 107.2 | 130.6 | 118.6 | 144.6 | 138.4 | 166.7 |
| | 111 | 50.1 | 85.3 | 64.0 | 85.9 | 76.3 | 109.0 | 102.9 | 126.7 | 120.7 | 148.1 | 137.0 | 164.2 |
| Decreasing: | | | | | | | | | | | | | |
| 6 | 15 | 46.3 | 80.6 | 72.0 | 102.3 | 86.8 | 121.7 | 105.6 | 126.1 | 110.8 | 131.7 | 110.3 | 135.5 |
| | 43 | 45.9 | 79.1 | 71.5 | 96.1 | 87.9 | 125.4 | 99.6 | 122.9 | 109.5 | 134.6 | 109.5 | 136.0 |
| | 81 | 43.9 | 77.5 | 72.1 | 101.7 | 86.8 | 122.2 | 104.7 | 128.9 | 112.5 | 137.6 | 109.4 | 134.8 |
| 8 | 14 | 51.7 | 89.7 | 80.8 | 115.7 | 104.0 | 144.5 | 135.9 | 159.6 | 144.9 | 171.0 | 146.9 | 176.9 |
| | 53 | 46.4 | 82.9 | 81.6 | 102.9 | 101.7 | 137.2 | 127.8 | 148.4 | 144.8 | 167.5 | 146.5 | 171.9 |
| | 73 | 49.5 | 87.6 | 80.4 | 102.3 | 102.3 | 141.1 | 137.9 | 161.4 | 144.5 | 166.6 | 146.8 | 173.4 |
| Unthinned: | | | | | | | | | | | | | |
| C | 22 | 97.8 | 147.8 | 147.8 | 183.1 | 183.1 | 224.1 | 224.1 | 245.6 | 245.6 | 267.9 | 267.9 | 272.9 |
| | 25 | 90.9 | 141.2 | 141.2 | 181.6 | 181.6 | 225.9 | 225.9 | 242.6 | 242.6 | 261.0 | 261.0 | 272.9 |
| | 71 | 70.2 | 114.3 | 114.3 | 149.9 | 149.9 | 181.9 | 181.9 | 201.5 | 201.9 | 216.4 | 216.4 | 232.2 |

[a] Stand age in parentheses.

[b] Plot 51 abandoned 1989 because of severe root rot.

**Table 5b—Basal area per hectare by treatment, plot, period, year, and age**

| | | Calibration | | Period 1 | | Period 2 | | Period 3 | | Period 4 | | Period 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | Plot | After cut 1966 (19)[a] | Before cut 1970 (23) | After cut 1970 (23) | Before cut 1973 (26) | After cut 1973 (26) | Before cut 1977 (30) | After cut 1977 (30) | Before cut 1980 (33) | After cut 1980 (33) | Before cut 1984 (37) | After cut 1984 (37) | 1989 (42) |
| | | *Square meters* | | | | | | | | | | | |
| Fixed: | | | | | | | | | | | | | |
| 1[b] | 21 | 10.3 | 17.9 | 12.1 | 17.8 | 13.3 | 19.6 | 14.3 | 18.2 | 14.8 | 19.1 | 15.1 | 18.9 |
| | 33 | 10.1 | 18.3 | 12.2 | 17.9 | 13.1 | 19.5 | 14.8 | 18.8 | 14.5 | 18.6 | 15.6 | 19.9 |
| | 51 | 9.5 | 16.2 | 12.1 | 16.0 | 13.0 | 17.9 | 12.8 | 14.5 | 13.6 | 17.1 | 15.5 | 19.7 |
| 3 | 31 | 10.1 | 17.2 | 14.2 | 20.0 | 17.0 | 24.3 | 21.3 | 26.4 | 23.1 | 28.8 | 25.4 | 31.3 |
| | 42 | 11.7 | 20.4 | 14.3 | 19.9 | 15.9 | 23.1 | 21.3 | 26.3 | 23.1 | 28.0 | 24.0 | 29.7 |
| | 52 | 10.1 | 17.4 | 14.2 | 19.3 | 16.7 | 22.9 | 19.9 | 24.0 | 24.0 | 29.9 | 24.0 | 29.3 |
| 5 | 12 | 11.1 | 18.9 | 16.4 | 23.3 | 21.2 | 29.6 | 28.0 | 33.9 | 30.8 | 36.7 | 32.4 | 38.8 |
| | 41 | 11.7 | 19.7 | 16.4 | 23.5 | 20.9 | 29.6 | 28.0 | 34.0 | 31.0 | 37.1 | 32.6 | 39.3 |
| | 72 | 10.7 | 18.2 | 16.4 | 21.9 | 20.8 | 27.1 | 27.1 | 32.2 | 31.1 | 36.0 | 32.6 | 38.7 |
| 7 | 11 | 12.0 | 20.3 | 18.7 | 26.3 | 24.7 | 33.8 | 33.8 | 39.7 | 38.9 | 45.7 | 41.2 | 48.0 |
| | 23 | 10.7 | 18.7 | 18.3 | 25.2 | 24.7 | 33.1 | 33.1 | 39.2 | 38.8 | 44.8 | 41.2 | 47.9 |
| | 63 | 11.2 | 18.7 | 18.7 | 23.6 | 23.6 | 31.3 | 31.3 | 36.3 | 36.3 | 42.2 | 41.0 | 47.3 |
| Increasing: | | | | | | | | | | | | | |
| 2 | 82 | 11.3 | 20.2 | 12.1 | 17.1 | 13.8 | 20.5 | 17.9 | 22.3 | 20.3 | 25.2 | 22.8 | 28.3 |
| | 91 | 10.3 | 17.7 | 11.8 | 15.4 | 14.2 | 21.3 | 17.1 | 20.5 | 20.5 | 25.8 | 22.7 | 28.3 |
| | 101 | 12.0 | 20.2 | 11.7 | 17.2 | 13.9 | 20.1 | 18.4 | 22.7 | 20.5 | 24.6 | 22.0 | 27.1 |
| 4 | 13 | 11.9 | 20.8 | 14.2 | 19.6 | 17.1 | 24.9 | 24.3 | 28.8 | 28.2 | 33.8 | 31.2 | 37.6 |
| | 62 | 10.8 | 19.2 | 14.9 | 20.7 | 18.8 | 26.6 | 24.6 | 30.0 | 27.2 | 33.2 | 31.8 | 38.3 |
| | 111 | 11.5 | 19.6 | 14.7 | 19.7 | 17.5 | 25.0 | 23.6 | 29.1 | 27.7 | 34.0 | 31.5 | 37.7 |
| Decreasing: | | | | | | | | | | | | | |
| 6 | 15 | 10.6 | 18.5 | 16.5 | 23.5 | 19.9 | 27.9 | 24.2 | 28.9 | 25.4 | 30.2 | 25.3 | 31.1 |
| | 43 | 10.5 | 18.2 | 16.4 | 22.1 | 20.2 | 28.8 | 22.9 | 28.2 | 25.1 | 30.9 | 25.1 | 31.2 |
| | 81 | 10.1 | 17.8 | 16.5 | 23.4 | 19.9 | 28.1 | 24.0 | 29.6 | 25.8 | 31.6 | 25.1 | 30.9 |
| 8 | 14 | 11.9 | 20.6 | 18.5 | 26.6 | 23.9 | 33.2 | 31.2 | 36.6 | 33.3 | 39.3 | 33.7 | 40.6 |
| | 53 | 10.6 | 19.0 | 18.7 | 23.6 | 23.3 | 31.5 | 29.3 | 34.1 | 33.2 | 38.4 | 33.6 | 39.5 |
| | 73 | 11.4 | 20.1 | 18.5 | 23.5 | 23.5 | 32.4 | 31.7 | 37.0 | 33.2 | 38.2 | 33.7 | 39.8 |
| Unthinned: | | | | | | | | | | | | | |
| C | 22 | 22.5 | 33.9 | 33.9 | 42.0 | 42.0 | 51.4 | 51.4 | 56.4 | 56.4 | 61.5 | 61.5 | 62.6 |
| | 25 | 20.9 | 32.4 | 32.4 | 41.7 | 41.7 | 51.9 | 51.9 | 55.7 | 55.7 | 59.9 | 59.9 | 62.6 |
| | 71 | 16.1 | 26.2 | 26.2 | 34.4 | 34.4 | 41.8 | 41.8 | 46.3 | 46.3 | 49.7 | 49.7 | 53.3 |

[a] Stand age in parentheses.

[b] Plot 51 abandoned 1989 because of severe root rot.

**Table 6a—Quadratic mean diameter of all live trees by treatment, plot, period, year and age**

| | | Calibration | | Period 1 | | Period 2 | | Period 3 | | Period 4 | | Period 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | Plot | After cut 1966 (19)[a] | Before cut 1970 (23) | After cut 1970 (23) | Before cut 1973 (26) | After cut 1973 (26) | Before cut 1977 (30) | After cut 1977 (30) | Before cut 1980 (33) | After cut 1980 (33) | Before cut 1984 (37) | After cut 1984 (37) | 1989 (42) |
| | | *Inches* | | | | | | | | | | | |
| Fixed: | | | | | | | | | | | | | |
| 1[b] | 21 | 4.9 | 6.4 | 6.9 | 8.3 | 8.7 | 10.6 | 11.0 | 12.4 | 12.6 | 14.3 | 14.8 | 16.6 |
| | 33 | 4.7 | 6.4 | 6.6 | 8.1 | 8.2 | 10.2 | 10.4 | 11.7 | 12.0 | 13.6 | 13.9 | 15.6 |
| | 51 | 4.6 | 6.3 | 6.3 | 7.8 | 8.0 | 9.9 | 10.4 | 11.7 | 12.0 | 13.5 | 13.8 | 15.5 |
| 3 | 31 | 4.8 | 6.3 | 6.4 | 7.7 | 7.8 | 9.4 | 9.6 | 10.7 | 10.7 | 12.0 | 12.3 | 13.6 |
| | 42 | 5.3 | 7.0 | 7.3 | 8.7 | 8.8 | 10.6 | 10.8 | 12.0 | 12.1 | 13.4 | 13.9 | 15.4 |
| | 52 | 4.8 | 6.4 | 6.7 | 8.2 | 8.4 | 10.1 | 10.1 | 11.3 | 11.3 | 12.6 | 13.2 | 14.9 |
| 5 | 12 | 5.1 | 6.7 | 6.9 | 8.2 | 8.6 | 10.1 | 10.2 | 11.2 | 11.2 | 12.3 | 12.5 | 13.7 |
| | 41 | 5.3 | 6.9 | 7.2 | 8.6 | 8.7 | 10.4 | 10.4 | 11.5 | 11.6 | 12.7 | 12.8 | 14.0 |
| | 72 | 4.9 | 6.5 | 6.6 | 7.8 | 7.8 | 9.1 | 9.1 | 9.9 | 10.0 | 11.0 | 11.1 | 12.1 |
| 7 | 11 | 5.3 | 6.9 | 7.0 | 8.3 | 8.4 | 9.8 | 9.8 | 10.6 | 10.8 | 11.7 | 11.8 | 12.9 |
| | 23 | 4.9 | 6.6 | 6.5 | 7.7 | 7.8 | 9.2 | 9.2 | 10.0 | 10.1 | 10.9 | 11.0 | 11.9 |
| | 63 | 4.8 | 6.5 | 6.5 | 7.8 | 7.8 | 9.1 | 9.1 | 10.0 | 10.0 | 10.9 | 10.9 | 11.9 |
| Increasing: | | | | | | | | | | | | | |
| 2 | 82 | 5.0 | 6.7 | 6.9 | 8.4 | 8.6 | 10.4 | 10.7 | 11.9 | 12.1 | 13.5 | 13.8 | 15.4 |
| | 91 | 4.7 | 6.4 | 6.6 | 8.0 | 8.0 | 9.9 | 10.1 | 11.2 | 11.2 | 12.6 | 12.8 | 14.3 |
| | 101 | 5.2 | 6.9 | 7.2 | 8.7 | 8.9 | 10.9 | 11.1 | 12.3 | 12.5 | 14.0 | 14.4 | 16.0 |
| 4 | 13 | 5.3 | 7.1 | 7.5 | 9.1 | 9.4 | 11.3 | 11.4 | 12.6 | 12.7 | 13.9 | 13.8 | 15.2 |
| | 62 | 4.7 | 6.3 | 6.5 | 7.9 | 8.0 | 9.6 | 9.6 | 10.6 | 10.7 | 11.8 | 11.9 | 13.2 |
| | 111 | 5.1 | 6.7 | 6.9 | 8.3 | 8.4 | 10.3 | 10.4 | 11.5 | 11.6 | 12.8 | 12.9 | 14.2 |
| Decreasing: | | | | | | | | | | | | | |
| 6 | 15 | 4.9 | 6.6 | 6.7 | 8.1 | 8.1 | 9.7 | 9.7 | 10.8 | 10.9 | 12.1 | 12.5 | 13.8 |
| | 43 | 4.8 | 6.4 | 6.5 | 7.8 | 8.0 | 9.6 | 9.7 | 10.7 | 10.9 | 12.0 | 12.4 | 13.9 |
| | 81 | 4.7 | 6.4 | 6.5 | 7.8 | 7.8 | 9.4 | 9.6 | 10.6 | 10.9 | 12.0 | 12.7 | 14.1 |
| 8 | 14 | 5.3 | 7.1 | 7.1 | 8.6 | 8.8 | 10.4 | 10.5 | 11.5 | 11.7 | 12.8 | 13.4 | 14.7 |
| | 53 | 4.9 | 6.6 | 6.6 | 7.7 | 7.8 | 9.1 | 9.1 | 9.9 | 9.9 | 10.8 | 10.8 | 11.8 |
| | 73 | 5.1 | 6.7 | 7.0 | 8.3 | 8.3 | 9.8 | 9.9 | 10.8 | 11.2 | 12.1 | 12.2 | 13.3 |
| Unthinned: | | | | | | | | | | | | | |
| C | 22 | 3.7 | 4.4 | 4.4 | 5.0 | 5.0 | 5.7 | 5.7 | 6.2 | 6.2 | 6.7 | 6.7 | 7.4 |
| | 25 | 3.5 | 4.3 | 4.3 | 4.9 | 4.9 | 5.6 | 5.6 | 6.1 | 6.1 | 6.8 | 6.8 | 7.8 |
| | 71 | 3.4 | 4.3 | 4.3 | 4.9 | 4.9 | 5.5 | 5.5 | 6.0 | 6.0 | 6.7 | 6.7 | 7.4 |

[a] Stand age in parentheses.

[b] Plot 51 abandoned 1989 because of severe root rot.

**Table 6b—Quadratic mean diameter of all live trees by treatment, plot, period, year and age**

| Treatment | Plot | Calibration | | Period 1 | | Period 2 | | Period 3 | | Period 4 | | Period 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | After cut 1966 (19)[a] | Before cut 1970 (23) | After cut 1970 (23) | Before cut 1973 (26) | After cut 1973 (26) | Before cut 1977 (30) | After cut 1977 (30) | Before cut 1980 (33) | After cut 1980 (33) | Before cut 1984 (37) | After cut 1984 (37) | 1989 (42) |
| | | *Centimeters* | | | | | | | | | | | |
| Fixed: | | | | | | | | | | | | | |
| 1[b] | 21 | 12.4 | 16.3 | 17.5 | 21.1 | 22.1 | 26.9 | 27.9 | 31.5 | 32.0 | 36.3 | 37.6 | 42.2 |
| | 33 | 11.9 | 16.3 | 16.8 | 20.6 | 20.8 | 25.9 | 26.4 | 29.7 | 30.5 | 34.5 | 35.3 | 39.6 |
| | 51 | 11.7 | 16.0 | 16.0 | 19.8 | 20.3 | 25.1 | 26.4 | 29.7 | 30.5 | 34.3 | 35.1 | 39.4 |
| 3 | 31 | 12.2 | 16.0 | 16.3 | 19.6 | 19.8 | 23.9 | 24.4 | 27.2 | 27.2 | 30.5 | 31.2 | 34.5 |
| | 42 | 13.5 | 17.8 | 18.5 | 22.1 | 22.4 | 26.9 | 27.4 | 30.5 | 30.7 | 34.0 | 35.3 | 39.1 |
| | 52 | 12.2 | 16.3 | 17.0 | 20.8 | 21.3 | 25.7 | 25.7 | 28.7 | 28.7 | 32.0 | 33.5 | 37.8 |
| 5 | 12 | 13.0 | 17.0 | 17.5 | 20.8 | 21.8 | 25.7 | 25.9 | 28.4 | 28.4 | 31.2 | 31.8 | 34.8 |
| | 41 | 13.5 | 17.5 | 18.3 | 21.8 | 22.1 | 26.4 | 26.4 | 29.2 | 29.5 | 32.3 | 32.5 | 35.6 |
| | 72 | 12.4 | 16.5 | 16.8 | 19.8 | 19.8 | 23.1 | 23.1 | 25.1 | 25.4 | 27.9 | 28.2 | 30.7 |
| 7 | 11 | 13.5 | 17.5 | 17.8 | 21.1 | 21.3 | 24.9 | 24.9 | 26.9 | 27.4 | 29.7 | 30.0 | 32.8 |
| | 23 | 12.4 | 16.8 | 16.5 | 19.6 | 19.8 | 23.4 | 23.4 | 25.4 | 25.7 | 27.7 | 27.9 | 30.2 |
| | 63 | 12.2 | 16.5 | 16.5 | 19.8 | 19.8 | 23.1 | 23.1 | 25.4 | 25.4 | 27.7 | 27.7 | 30.2 |
| Increasing: | | | | | | | | | | | | | |
| 2 | 82 | 12.7 | 17.0 | 17.5 | 21.3 | 21.8 | 26.4 | 27.2 | 30.2 | 30.7 | 34.3 | 35.1 | 39.1 |
| | 91 | 11.9 | 16.3 | 16.8 | 20.3 | 20.3 | 25.1 | 25.7 | 28.4 | 28.4 | 32.0 | 32.5 | 36.3 |
| | 101 | 13.2 | 17.5 | 18.3 | 22.1 | 22.6 | 27.7 | 28.2 | 31.2 | 31.8 | 35.6 | 36.6 | 40.6 |
| 4 | 13 | 13.5 | 18.0 | 19.1 | 23.1 | 23.9 | 28.7 | 29.0 | 32.0 | 32.3 | 35.3 | 35.1 | 38.6 |
| | 62 | 11.9 | 16.0 | 16.5 | 20.1 | 20.3 | 24.4 | 24.4 | 26.9 | 27.2 | 30.0 | 30.2 | 33.5 |
| | 111 | 13.0 | 17.0 | 17.5 | 21.1 | 21.3 | 26.2 | 26.4 | 29.2 | 29.5 | 32.5 | 32.8 | 36.1 |
| Decreasing: | | | | | | | | | | | | | |
| 6 | 15 | 12.4 | 16.8 | 17.0 | 20.6 | 20.6 | 24.6 | 24.6 | 27.4 | 27.7 | 30.7 | 31.8 | 35.1 |
| | 43 | 12.2 | 16.3 | 16.5 | 19.8 | 20.3 | 24.4 | 24.6 | 27.2 | 27.7 | 30.5 | 31.5 | 35.3 |
| | 81 | 11.9 | 16.3 | 16.5 | 19.8 | 19.8 | 23.9 | 24.4 | 26.9 | 27.7 | 30.5 | 32.3 | 35.8 |
| 8 | 14 | 13.5 | 18.0 | 18.0 | 21.8 | 22.4 | 26.4 | 26.7 | 29.2 | 29.7 | 32.5 | 34.0 | 37.3 |
| | 53 | 12.4 | 16.8 | 16.8 | 19.6 | 19.8 | 23.1 | 23.1 | 25.1 | 25.1 | 27.4 | 27.4 | 30.0 |
| | 73 | 13.0 | 17.0 | 17.8 | 21.1 | 21.1 | 24.9 | 25.1 | 27.4 | 28.4 | 30.7 | 31.0 | 33.8 |
| Unthinned: | | | | | | | | | | | | | |
| C | 22 | 9.4 | 11.2 | 11.2 | 12.7 | 12.7 | 14.5 | 14.5 | 15.7 | 15.7 | 17.0 | 17.0 | 18.8 |
| | 25 | 8.9 | 10.9 | 10.9 | 12.4 | 12.4 | 14.2 | 14.2 | 15.5 | 15.5 | 17.3 | 17.3 | 19.8 |
| | 71 | 8.6 | 10.9 | 10.9 | 12.4 | 12.4 | 14.0 | 14.0 | 15.2 | 15.2 | 17.0 | 17.0 | 18.8 |

[a] Stand age in parentheses.

[b] Plot 51 abandoned 1989 because of severe root rot.

**Table 7a—Quadratic mean diameters of largest 40 trees per acre, crop trees, and largest 80 trees per acre by treatment, period, and year**

| | | After cut | Before cut | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment | QMD | 1966 (19)[a] | 1970 (23) | 1973 (26) | 1977 (30) | 1980 (33) | 1984 (37) | 1989 (42) |
| | | *Inches* | | | | | | |
| Fixed: | | | | | | | | |
| 1[b] | largest 40 | 6.5 | 8.6 | 10.2 | 12.2 | 13.6 | 15.2 | 17.0 |
| | crop trees | 5.6 | 7.4 | 9.0 | 11.1 | 12.5 | 14.2 | 16.1 |
| | largest 80 | 6.1 | 8.0 | 9.5 | 11.5 | 12.6 | 13.9 | —[c] |
| 3 | largest 40 | 6.6 | 8.6 | 10.1 | 12.0 | 13.3 | 14.8 | 16.5 |
| | crop trees | 5.9 | 7.8 | 9.2 | 11.0 | 12.3 | 13.6 | 15.1 |
| | largest 80 | 6.3 | 8.2 | 9.6 | 11.4 | 12.6 | 13.9 | 15.5 |
| 5 | largest 40 | 6.8 | 8.8 | 10.3 | 12.2 | 13.3 | 14.6 | 16.1 |
| | crop trees | 6.1 | 8.0 | 9.5 | 11.2 | 12.3 | 13.5 | 14.8 |
| | largest 80 | 6.4 | 8.3 | 9.8 | 11.5 | 12.6 | 13.8 | 15.1 |
| 7 | largest 40 | 6.7 | 8.7 | 10.3 | 12.0 | 13.2 | 14.4 | 15.7 |
| | crop trees | 5.7 | 7.5 | 9.0 | 10.5 | 11.5 | 12.6 | 13.7 |
| | largest 80 | 6.3 | 8.2 | 9.7 | 11.4 | 12.4 | 13.6 | 14.8 |
| Increasing: | | | | | | | | |
| 2 | largest 40 | 6.6 | 8.5 | 9.9 | 11.9 | 13.2 | 14.7 | 16.5 |
| | crop trees | 5.8 | 7.7 | 9.3 | 11.1 | 12.2 | 13.7 | 15.3 |
| | largest 80 | 6.2 | 8.1 | 9.5 | 11.3 | 12.6 | 14.0 | 15.6 |
| 4 | largest 40 | 6.5 | 8.5 | 10.1 | 12.1 | 13.3 | 14.7 | 16.2 |
| | crop trees | 5.9 | 7.8 | 9.3 | 11.2 | 12.4 | 13.7 | 15.0 |
| | largest 80 | 6.3 | 8.2 | 9.7 | 11.6 | 12.8 | 14.1 | 15.5 |
| Decreasing: | | | | | | | | |
| 6 | largest 40 | 6.4 | 8.4 | 9.9 | 11.7 | 13.0 | 14.3 | 15.9 |
| | crop trees | 5.7 | 7.6 | 9.0 | 10.8 | 12.0 | 13.3 | 15.0 |
| | largest 80 | 6.1 | 8.0 | 9.5 | 11.3 | 12.4 | 13.8 | 15.2 |
| 8 | largest 40 | 6.7 | 8.8 | 10.4 | 12.2 | 13.4 | 14.7 | 16.1 |
| | crop trees | 5.9 | 8.0 | 9.6 | 11.1 | 12.1 | 13.2 | 14.6 |
| | largest 80 | 6.4 | 8.4 | 10.0 | 11.7 | 12.8 | 13.7 | 15.3 |
| Unthinned: | | | | | | | | |
| C | largest 40 | 6.5 | 8.3 | 9.5 | 10.9 | 11.7 | 12.7 | 13.8 |
| | crop trees | 5.8 | 7.4 | 8.6 | 9.7 | 10.5 | 11.2 | 12.2 |
| | largest 80 | 6.1 | 7.8 | 9.0 | 10.4 | 11.2 | 12.1 | 13.2 |

[a] Stand age in parentheses.

[b] Treatment 1 mean omits plot 51, because of severe root rot.

[c] Number per acre <80.

**Table 7b—Quadratic mean diameters of largest 100 trees per hectare, crop trees, and largest 200 trees per hectare by treatment, period, and year**

| | | After cut | Before cut | | | | | |
|---|---|---|---|---|---|---|---|---|
| Treatment | QMD | 1966 (19)[a] | 1970 (23) | 1973 (26) | 1977 (30) | 1980 (33) | 1984 (37) | 1989 (42) |
| | | Centimeters | | | | | | |
| Fixed: | | | | | | | | |
| 1[b] | largest 100 | 16.5 | 21.7 | 25.8 | 31.0 | 34.4 | 38.5 | 43.1 |
| | crop trees | 14.2 | 18.8 | 22.9 | 28.2 | 31.8 | 36.1 | 40.9 |
| | largest 200 | 15.5 | 20.4 | 24.2 | 29.1 | 32.1 | 35.2 | —[c] |
| 3 | largest 100 | 16.8 | 21.8 | 25.7 | 30.5 | 33.7 | 37.6 | 41.8 |
| | crop trees | 15.0 | 19.8 | 23.4 | 27.9 | 31.2 | 34.5 | 38.4 |
| | largest 200 | 16.0 | 20.8 | 24.5 | 29.0 | 32.0 | 35.4 | 39.4 |
| 5 | largest 100 | 17.2 | 22.3 | 26.2 | 30.9 | 33.8 | 37.0 | 40.9 |
| | crop trees | 15.5 | 20.3 | 24.1 | 28.4 | 31.2 | 34.3 | 37.6 |
| | largest 200 | 16.3 | 21.1 | 25.0 | 29.1 | 31.9 | 35.0 | 38.4 |
| 7 | largest 100 | 17.1 | 22.1 | 26.1 | 30.6 | 33.4 | 36.5 | 39.8 |
| | crop trees | 14.5 | 19.1 | 22.9 | 26.7 | 29.2 | 32.0 | 34.8 |
| | largest 200 | 16.1 | 20.8 | 24.6 | 28.9 | 31.6 | 34.5 | 37.6 |
| Increasing: | | | | | | | | |
| 2 | largest 100 | 16.7 | 21.6 | 25.1 | 30.2 | 33.5 | 37.4 | 41.9 |
| | crop trees | 14.7 | 19.6 | 23.6 | 28.2 | 31.0 | 34.8 | 38.9 |
| | largest 200 | 15.8 | 20.7 | 24.0 | 28.7 | 32.0 | 35.6 | 39.7 |
| 4 | largest 100 | 16.6 | 21.5 | 25.7 | 30.6 | 33.8 | 37.3 | 41.1 |
| | crop trees | 15.0 | 19.8 | 23.6 | 28.4 | 31.5 | 34.8 | 38.1 |
| | largest 200 | 15.9 | 20.8 | 24.6 | 29.5 | 32.5 | 35.8 | 39.3 |
| Decreasing: | | | | | | | | |
| 6 | largest 100 | 16.3 | 21.3 | 25.1 | 29.7 | 32.9 | 36.4 | 40.5 |
| | crop trees | 14.5 | 19.3 | 22.9 | 27.4 | 30.5 | 33.8 | 38.1 |
| | largest 200 | 15.4 | 20.3 | 24.2 | 28.7 | 31.6 | 35.0 | 38.7 |
| 8 | largest 100 | 17.1 | 22.3 | 26.3 | 31.1 | 34.0 | 37.3 | 41.0 |
| | crop trees | 15.0 | 20.3 | 24.4 | 28.2 | 30.7 | 33.5 | 37.1 |
| | largest 200 | 16.2 | 21.3 | 25.3 | 29.8 | 32.5 | 34.7 | 38.8 |
| Unthinned: | | | | | | | | |
| C | largest 100 | 16.5 | 21.1 | 24.1 | 26.9 | 29.7 | 32.3 | 35.0 |
| | crop trees | 14.7 | 18.8 | 21.8 | 24.6 | 26.7 | 28.4 | 31.0 |
| | largest 200 | 15.5 | 19.8 | 22.9 | 26.4 | 28.4 | 30.7 | 33.5 |

[a] Stand age in parentheses.

[b] Treatment 1 mean omits plot 51 because of severe root rot.

[c] Number per hectare <200.

## Table 8a—Total cubic volume (CVTS) per acre by treatment, plot, period, year and age

| Treatment | Plot | Calibration | | Period 1 | | Period 2 | | Period 3 | | Period 4 | | Period 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | After cut 1966 (19)[a] | Before cut 1970 (23) | After cut 1970 (23) | Before cut 1973 (26) | After cut 1973 (26) | Before cut 1977 (30) | After cut 1977 (30) | Before cut 1980 (33) | After cut 1980 (33) | Before cut 1984 (37) | After cut 1984 (37) | 1989 (42) |
| | | Cubic feet | | | | | | | | | | | |
| Fixed: | | | | | | | | | | | | | |
| 1[b] | 21 | 614 | 1390 | 959 | 1590 | 1201 | 2124 | 1564 | 2228 | 1822 | 2612 | 2087 | 2969 |
| | 33 | 644 | 1491 | 1006 | 1698 | 1252 | 2143 | 1646 | 2366 | 1828 | 2524 | 2134 | 3090 |
| | 51 | 551 | 1281 | 960 | 1435 | 1170 | 1862 | 1359 | 1685 | 1600 | 2204 | 2010 | 2870 |
| 3 | 31 | 609 | 1321 | 1100 | 1849 | 1574 | 2686 | 2355 | 3295 | 2879 | 4004 | 3546 | 4993 |
| | 42 | 739 | 1730 | 1225 | 1923 | 1535 | 2637 | 2436 | 3344 | 2928 | 3967 | 3406 | 4860 |
| | 52 | 607 | 1392 | 1145 | 1767 | 1536 | 2522 | 2178 | 2927 | 2927 | 4052 | 3267 | 4540 |
| 5 | 12 | 740 | 1618 | 1407 | 2320 | 2130 | 3503 | 3316 | 4485 | 4079 | 5324 | 4714 | 6452 |
| | 41 | 768 | 1679 | 1411 | 2344 | 2094 | 3378 | 3204 | 4380 | 3989 | 5295 | 4672 | 6476 |
| | 72 | 697 | 1492 | 1347 | 2093 | 1991 | 3079 | 3079 | 4084 | 3947 | 5215 | 4728 | 6369 |
| 7 | 11 | 788 | 1690 | 1554 | 2590 | 2438 | 3948 | 3948 | 5320 | 5211 | 6647 | 6011 | 7884 |
| | 23 | 667 | 1519 | 1485 | 2380 | 2336 | 3777 | 3777 | 5035 | 4992 | 6302 | 5801 | 7751 |
| | 63 | 744 | 1590 | 1590 | 2362 | 2362 | 3623 | 3623 | 4704 | 4704 | 6153 | 5984 | 7822 |
| Increasing: | | | | | | | | | | | | | |
| 2 | 82 | 773 | 1743 | 1049 | 1766 | 1438 | 2430 | 2131 | 2878 | 2625 | 3653 | 3327 | 4693 |
| | 91 | 648 | 1489 | 998 | 1511 | 1389 | 2359 | 1864 | 2581 | 2581 | 3642 | 3196 | 4477 |
| | 101 | 821 | 1724 | 1013 | 1691 | 1371 | 2315 | 2131 | 2910 | 2630 | 3517 | 3151 | 4365 |
| 4 | 13 | 822 | 1774 | 1235 | 1979 | 1733 | 2814 | 2748 | 3680 | 3618 | 4785 | 4417 | 5978 |
| | 62 | 687 | 1603 | 1260 | 1928 | 1765 | 2969 | 2734 | 3754 | 3419 | 4655 | 4449 | 6101 |
| | 111 | 826 | 1806 | 1365 | 2088 | 1859 | 3045 | 2874 | 3981 | 3798 | 5226 | 4838 | 6460 |
| Decreasing: | | | | | | | | | | | | | |
| 6 | 15 | 686 | 1487 | 1333 | 2171 | 1844 | 3066 | 2653 | 3561 | 3121 | 4160 | 3496 | 4891 |
| | 43 | 605 | 1397 | 1266 | 1930 | 1778 | 3108 | 2471 | 3433 | 3068 | 4187 | 3454 | 4915 |
| | 81 | 628 | 1443 | 1347 | 2258 | 1931 | 3134 | 2698 | 3798 | 3329 | 4454 | 3564 | 4984 |
| 8 | 14 | 824 | 1716 | 1552 | 2604 | 2353 | 3665 | 3461 | 4560 | 4153 | 5543 | 4795 | 6645 |
| | 53 | 673 | 1579 | 1554 | 2192 | 2166 | 3389 | 3155 | 4121 | 4020 | 5202 | 4559 | 6191 |
| | 73 | 819 | 1751 | 1627 | 2367 | 2367 | 3829 | 3746 | 4847 | 4373 | 5564 | 4919 | 6667 |
| Unthinned: | | | | | | | | | | | | | |
| C | 22 | 1324 | 2697 | 2697 | 3998 | 3998 | 5730 | 5730 | 7291 | 7291 | 8651 | 8651 | 10000 |
| | 25 | 1206 | 2496 | 2496 | 3806 | 3806 | 5625 | 5625 | 6853 | 6853 | 8289 | 8289 | 9983 |
| | 71 | 942 | 2086 | 2086 | 3196 | 3196 | 4512 | 4512 | 5616 | 5616 | 6980 | 6980 | 8527 |

[a] Stand are in parentheses.

[b] Plot 51 abandoned 1989 because of severe root rot.

**Table 8b—Total cubic volume (CVTS) per hectare by treatment, plot, period, year and age**

| | | Calibration | | Period 1 | | Period 2 | | Period 3 | | Period 4 | | Period 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | Plot | After cut 1966 (19)[a] | Before cut 1970 (23) | After cut 1970 (23) | Before cut 1973 (26) | After cut 1973 (26) | Before cut 1977 (30) | After cut 1977 (30) | Before cut 1980 (33) | After cut 1980 (33) | Before cut 1984 (37) | After cut 1984 (37) | 1989 (42) |
| | | *Cubic meters* | | | | | | | | | | | |
| Fixed: | | | | | | | | | | | | | |
| 1[b] | 21 | 43 | 97 | 67 | 111 | 84 | 149 | 109 | 156 | 127 | 183 | 146 | 208 |
| | 33 | 45 | 104 | 70 | 119 | 88 | 150 | 115 | 166 | 128 | 177 | 149 | 216 |
| | 51 | 39 | 90 | 67 | 100 | 82 | 130 | 95 | 118 | 112 | 154 | 141 | 201 |
| 3 | 31 | 43 | 92 | 77 | 129 | 110 | 188 | 165 | 231 | 201 | 280 | 248 | 349 |
| | 42 | 52 | 121 | 86 | 135 | 107 | 184 | 170 | 234 | 205 | 278 | 238 | 340 |
| | 52 | 42 | 97 | 80 | 124 | 107 | 176 | 152 | 205 | 205 | 283 | 229 | 318 |
| 5 | 12 | 52 | 113 | 98 | 162 | 149 | 245 | 232 | 314 | 285 | 372 | 330 | 451 |
| | 41 | 54 | 117 | 99 | 164 | 146 | 236 | 224 | 306 | 279 | 371 | 327 | 453 |
| | 72 | 49 | 104 | 94 | 146 | 139 | 215 | 215 | 286 | 276 | 365 | 331 | 446 |
| 7 | 11 | 55 | 118 | 109 | 181 | 171 | 276 | 276 | 372 | 365 | 465 | 421 | 552 |
| | 23 | 47 | 106 | 104 | 167 | 163 | 264 | 264 | 352 | 349 | 441 | 406 | 542 |
| | 63 | 52 | 111 | 111 | 165 | 165 | 254 | 254 | 329 | 329 | 431 | 419 | 547 |
| Increasing: | | | | | | | | | | | | | |
| 2 | 82 | 54 | 122 | 73 | 124 | 101 | 170 | 149 | 201 | 184 | 256 | 233 | 328 |
| | 91 | 45 | 104 | 70 | 106 | 97 | 165 | 130 | 181 | 181 | 255 | 224 | 313 |
| | 101 | 57 | 121 | 71 | 118 | 96 | 162 | 149 | 204 | 184 | 246 | 220 | 305 |
| 4 | 13 | 57 | 124 | 86 | 138 | 121 | 197 | 192 | 257 | 253 | 335 | 309 | 418 |
| | 62 | 48 | 112 | 88 | 135 | 123 | 208 | 191 | 263 | 239 | 326 | 311 | 427 |
| | 111 | 58 | 126 | 95 | 146 | 130 | 213 | 201 | 279 | 266 | 366 | 339 | 452 |
| Decreasing: | | | | | | | | | | | | | |
| 6 | 15 | 48 | 104 | 93 | 152 | 129 | 215 | 186 | 249 | 218 | 291 | 245 | 342 |
| | 43 | 42 | 98 | 89 | 135 | 124 | 217 | 173 | 240 | 215 | 293 | 242 | 344 |
| | 81 | 44 | 101 | 94 | 158 | 135 | 219 | 189 | 266 | 233 | 312 | 249 | 349 |
| 8 | 14 | 58 | 120 | 109 | 182 | 165 | 256 | 242 | 319 | 291 | 388 | 335 | 465 |
| | 53 | 47 | 110 | 109 | 153 | 152 | 237 | 221 | 288 | 281 | 364 | 319 | 433 |
| | 73 | 57 | 122 | 114 | 166 | 166 | 268 | 262 | 339 | 306 | 389 | 344 | 466 |
| Unthinned: | | | | | | | | | | | | | |
| C | 22 | 93 | 189 | 189 | 280 | 280 | 401 | 401 | 510 | 510 | 605 | 605 | 700 |
| | 25 | 84 | 175 | 175 | 266 | 266 | 394 | 394 | 480 | 480 | 580 | 580 | 699 |
| | 71 | 66 | 146 | 146 | 224 | 224 | 316 | 316 | 393 | 393 | 488 | 488 | 597 |

[a] Stand age in parentheses.

[b] Plot 51 abandoned 1989 because of severe root rot.

## Table 9a—Average per acre stand statistics, by treatment, year, and age

| Treatment | Year | Age | Period | H40 | After thinning: Trees left | After thinning: QMD all | After thinning: QMD crop | After thinning: Basal area | CVTS | Removed in thinning: Trees cut | Removed in thinning: QMD | Removed in thinning: Basal area | Removed in thinning: CVTS | Removed in thinning: CV6 | d/D | Mortality: Trees dead | Mortality: QMD | Mortality: Basal area | Mortality: CVTS | Cum Yield: Net CVTS | Cum Yield: Gross CVTS | Cum Yield: Net CV6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Ft | | -- Inches -- | | $Ft^2$ | $Ft^3$ | | In | $Ft^2$ | - Cubic feet - | | | | In | $Ft^2$ | $Ft^3$ | --- Cubic feet --- | | |
| Fixed: | | | | | | | | | | | | | | | | | | | | | | |
| 1[a] | 1966 | 19 | 0 | 40 | 355 | 4.8 | 5.6 | 44.5 | 629 | | | | 450[b] | | | | | | | 1079 | 1079 | 0 |
| | 1970 | 23 | 1 | 50 | 215 | 6.8 | 7.4 | 53.0 | 982 | 135 | 5.9 | 25.8 | 458 | 29 | 0.92 | 5.0 | 3.8 | 0.4 | 4 | 1890 | 1894 | 230 |
| | 1973 | 26 | 2 | 59 | 148 | 8.5 | 9.1 | 57.4 | 1226 | 65 | 7.6 | 20.4 | 418 | 163 | .92 | 2.5 | 7.7 | .8 | 16 | 2551 | 2571 | 905 |
| | 1977 | 30 | 3 | 69 | 102 | 10.7 | 11.1 | 63.5 | 1605 | 43 | 9.7 | 21.7 | 528 | 391 | .94 | 2.5 | 6.1 | .5 | 11 | 3458 | 3489 | 1893 |
| | 1980 | 33 | 4 | 79 | 78 | 12.3 | 12.5 | 63.8 | 1824 | 25 | 11.2 | 16.8 | 472 | 391 | .93 | 0 | 0 | 0 | 0 | 4150 | 4181 | 2594 |
| | 1984 | 37 | 5 | 85 | 60 | 14.4 | 14.3 | 67.0 | 2110 | 18 | 12.6 | 15.2 | 458 | 411 | .90 | 0 | 0 | 0 | 0 | 4893 | 4924 | 3345 |
| | 1989 | 42 | 6 | 97 | 60 | 16.1 | 16.1 | 84.4 | 3029 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 5812 | 5843 | 4246 |
| 3 | 1966 | 19 | 0 | 37 | 348 | 5.0 | 5.9 | 46.3 | 652 | | | | 450 | | | | | | | 1102 | 1102 | 4 |
| | 1970 | 23 | 1 | 49 | 248 | 6.8 | 7.8 | 61.9 | 1156 | 92 | 5.9 | 18.0 | 325 | 22 | .92 | 11.7 | 3.8 | .9 | 13 | 1931 | 1944 | 313 |
| | 1973 | 26 | 2 | 56 | 193 | 8.3 | 9.2 | 72.0 | 1548 | 43 | 7.7 | 14.1 | 298 | 138 | .94 | 11.7 | 6.6 | 2.8 | 55 | 2621 | 2689 | 1032 |
| | 1977 | 30 | 3 | 68 | 162 | 10.2 | 11.0 | 90.7 | 2323 | 27 | 8.9 | 11.4 | 292 | 185 | .86 | 5.0 | 8.3 | 1.9 | 47 | 3687 | 3802 | 2148 |
| | 1980 | 33 | 4 | 76 | 145 | 11.4 | 12.3 | 101.9 | 2911 | 15 | 10.9 | 9.6 | 277 | 230 | .88 | 1.7 | 8.7 | .7 | 18 | 4553 | 4686 | 3058 |
| | 1984 | 37 | 5 | 84 | 115 | 13.1 | 13.6 | 106.5 | 3406 | 30 | 10.9 | 19.3 | 601 | 497 | .85 | 0 | 0 | 0 | 0 | 5649 | 5782 | 4155 |
| | 1989 | 42 | 6 | 98 | 113 | 14.6 | 15.1 | 131.1 | 4798 | 0 | 0 | 0 | 0 | 0 | 0 | 1.7 | 10.4 | 1.0 | 33 | 7040 | 7207 | 5537 |
| 5 | 1966 | 19 | 0 | 38 | 347 | 5.1 | 6.1 | 48.6 | 735 | | | | 450 | | | | | | | 1185 | 1185 | 10 |
| | 1970 | 23 | 1 | 50 | 277 | 6.9 | 8.0 | 71.3 | 1388 | 62 | 5.8 | 11.2 | 208 | 6 | .88 | 8.3 | 4.9 | 1.1 | 18 | 2046 | 2064 | 347 |
| | 1973 | 26 | 2 | 59 | 242 | 8.4 | 9.5 | 91.3 | 2072 | 32 | 7.1 | 8.4 | 181 | 60 | .90 | 3.3 | 8.2 | 1.2 | 27 | 2910 | 2955 | 1188 |
| | 1977 | 30 | 3 | 70 | 227 | 9.9 | 11.2 | 120.7 | 3200 | 10 | 9.2 | 4.6 | 120 | 78 | .85 | 5.0 | 7.4 | 1.5 | 38 | 4158 | 4241 | 2557 |
| | 1980 | 33 | 4 | 78 | 210 | 10.9 | 12.3 | 134.9 | 4005 | 17 | 10.5 | 10.5 | 311 | 258 | .96 | 0 | 0 | 0 | 0 | 5274 | 5357 | 3706 |
| | 1984 | 37 | 5 | 88 | 178 | 12.1 | 13.5 | 141.7 | 4705 | 28 | 10.8 | 17.8 | 573 | 466 | .86 | 3.3 | 6.7 | .8 | 23 | 6547 | 6653 | 5001 |
| | 1989 | 42 | 6 | 102 | 178 | 13.3 | 14.8 | 169.6 | 6432 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 8275 | 8381 | 6705 |
| 7 | 1966 | 19 | 0 | 38 | 360 | 5.0 | 5.7 | 49.2 | 733 | | | | 450 | | | | | | | 1183 | 1183 | 13 |
| | 1970 | 23 | 1 | 49 | 333 | 6.7 | 7.5 | 80.7 | 1543 | 13 | 4.0 | 3.0 | 57 | 6 | .99 | 13.3 | 4.7 | 1.6 | 29 | 2050 | 2078 | 306 |
| | 1973 | 26 | 2 | 59 | 305 | 8.0 | 8.9 | 105.9 | 2378 | 12 | 4.6 | 3.0 | 65 | 24 | .88 | 16.7 | 6.7 | 4.1 | 92 | 2950 | 3071 | 1215 |
| | 1977 | 30 | 3 | 70 | 297 | 9.4 | 10.5 | 142.6 | 3782 | 0 | 0 | 0 | 0 | 0 | 0 | 8.3 | 7.4 | 2.5 | 62 | 4354 | 4536 | 2694 |
| | 1980 | 33 | 4 | 78 | 287 | 10.3 | 11.5 | 165.6 | 4969 | 7 | 4.3 | 1.8 | 51 | 19 | .78 | 3.3 | 8.8 | 1.4 | 41 | 5592 | 5815 | 3955 |
| | 1984 | 37 | 5 | 88 | 260 | 11.2 | 12.6 | 179.2 | 5932 | 23 | 12.1 | 13.4 | 435 | 338 | .90 | 3.3 | 6.2 | .7 | 19 | 6990 | 7233 | 5367 |
| | 1989 | 42 | 6 | 101 | 255 | 12.2 | 13.7 | 207.9 | 7819 | 0 | 0 | 0 | 0 | 0 | 0 | 5.0 | 6.4 | 1.1 | 34 | 8877 | 9153 | 7255 |
| Increasing: | | | | | | | | | | | | | | | | | | | | | | |
| 2 | 1966 | 19 | 0 | 40 | 360 | 5.0 | 5.8 | 48.8 | 747 | | | | | | | | | | | 1197 | 1197 | 0 |
| | 1970 | 23 | 1 | 51 | 198 | 6.9 | 7.7 | 51.6 | 1020 | 148 | 6.3 | 32.8 | 632 | 122 | .95 | 3.75 | 5.0 | .5 | 36 | 2102 | 2138 | 350 |
| | 1973 | 26 | 2 | 58 | 155 | 8.5 | 9.3 | 60.8 | 1399 | 33 | 8.0 | 11.5 | 257 | 118 | .95 | 3.33 | 7.8 | 1.1 | 73 | 2738 | 2847 | 1066 |
| | 1977 | 30 | 3 | 67 | 127 | .6 | 11.1 | 77.5 | 2042 | 27 | 9.3 | 12.3 | 326 | 224 | .89 | .42 | 5.7 | .1 | 7 | 3707 | 3823 | 2131 |
| | 1980 | 33 | 4 | 76 | 115 | 1.9 | 12.2 | 88.9 | 2612 | 10 | 10.7 | 6.2 | 178 | 141 | .88 | .56 | 11.3 | .4 | 34 | 4454 | 4604 | 2900 |
| | 1984 | 37 | 5 | 86 | 97 | 3.7 | 13.7 | 97.9 | 3224 | 17 | 11.4 | 11.8 | 379 | 327 | .86 | .42 | 11.2 | .3 | 35 | 5446 | 5631 | 3902 |
| | 1989 | 42 | 6 | 99 | 97 | 5.2 | 15.3 | 121.6 | 4511 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 6733 | 6918 | 5170 |

**Table 9a—Average per acre stand statistics, by treatment, year, and age (continued)**

| Treatment | Year | Age | Period | H40 | After thinning: Trees left | After thinning: QMD all | After thinning: QMD crop | After thinning: Basal area | After thinning: CVTS | Removed in thinning: Trees cut | Removed in thinning: QMD | Removed in thinning: Basal area | Removed in thinning: CVTS | Removed in thinning: CV6 | d/D | Mortality: Trees dead | Mortality: QMD | Mortality: Basal area | Mortality: CVTS | Cum Yield: Net CVTS | Cum Yield: Gross CVTS | Cum Yield: Net CV6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *Ft* | | -- Inches -- | | *Ft²* | *Ft³* | | *In* | *Ft²* | - *Cubic feet* - | | | | *In* | *Ft²* | *Ft³* | --- *Cubic feet* --- | | |
| 4 | 1966 | 19 | 0 | 41 | 363 | 5.0 | 5.9 | 49.7 | 778 | | | | | | | | | | | 1228 | 1228 | 4 |
| | 1970 | 23 | 1 | 53 | 243 | 7.0 | 7.8 | 63.5 | 1286 | 112 | 6.1 | 22.9 | 441 | 51 | .91 | 2.08 | 4.7 | .3 | 18 | 2178 | 2196 | 387 |
| | 1973 | 26 | 2 | 60 | 197 | 8.6 | 9.4 | 77.7 | 1786 | 32 | 7.4 | 9.4 | 213 | 98 | .88 | 5.00 | 7.0 | 1.3 | 87 | 2889 | 2994 | 1190 |
| | 1977 | 30 | 3 | 69 | 180 | .5 | 11.2 | 105.4 | 2785 | 12 | 9.4 | 5.7 | 157 | 115 | .91 | 1.25 | 5.6 | .2 | 17 | 4046 | 4168 | 2473 |
| | 1980 | 33 | 4 | 78 | 165 | 1.7 | 12.4 | 120.8 | 3612 | 13 | 9.8 | 6.8 | 194 | 146 | .85 | .56 | 10.0 | .3 | 26 | 5066 | 5230 | 3534 |
| | 1984 | 37 | 5 | 87 | 153 | 2.9 | 13.7 | 137.1 | 4568 | 12 | 12.3 | 9.6 | 321 | 285 | .95 | 0 | 0 | 0 | 0 | 6343 | 6507 | 4815 |
| | 1989 | 42 | 6 | 100 | 152 | 14.2 | 15.0 | 164.8 | 6180 | 0 | 0 | 0 | 0 | 0 | 0 | .33 | 5.7 | .1 | 8 | 7955 | 8127 | 6414 |
| Decreasing: | | | | | | | | | | | | | | | | | | | | | | |
| 6 | 1966 | 19 | 0 | 37 | 360 | 4.8 | 5.7 | 45.4 | 639 | | | | | | | | | | | 1089 | 1089 | 0 |
| | 1970 | 23 | 1 | 48 | 307 | 6.6 | 7.6 | 71.9 | 1315 | 37 | 6.0 | 7.0 | 127 | 13 | .93 | 4.17 | 4.2 | .4 | 25 | 1892 | 1917 | 238 |
| | 1973 | 26 | 2 | 56 | 252 | 8.0 | 9.0 | 87.2 | 1851 | 43 | 7.3 | 10.1 | 269 | 86 | .93 | 3.89 | 6.3 | .9 | 50 | 2696 | 2771 | 1021 |
| | 1977 | 30 | 3 | 67 | 203 | 9.7 | 10.8 | 103.3 | 2607 | 43 | 9.2 | 12.3 | 496 | 333 | .96 | 1.25 | 6.4 | .3 | 26 | 3948 | 4049 | 2344 |
| | 1980 | 33 | 4 | 75 | 172 | 10.9 | 12.0 | 111.0 | 3172 | 30 | 9.6 | 16.1 | 425 | 309 | .89 | .56 | 8.4 | .2 | 17 | 4938 | 5055 | 3376 |
| | 1984 | 37 | 5 | 84 | 128 | 12.5 | 13.3 | 109.7 | 3504 | 42 | 10.5 | 23.1 | 762 | 614 | .87 | .42 | 11.3 | .3 | 37 | 6032 | 6187 | 4479 |
| | 1989 | 42 | 6 | 97 | 128 | 13.9 | 15.0 | 135.4 | 4930 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7457 | 7612 | 5895 |
| 8 | 1966 | 19 | 0 | 40 | 352 | 5.1 | 5.9 | 49.2 | 772 | | | | | | | | | | | 1222 | 1222 | 6 |
| | 1970 | 23 | 1 | 51 | 313 | 6.9 | 8.0 | 80.9 | 1578 | 32 | 6.1 | 5.8 | 104 | 21 | .90 | 1.67 | 4.4 | .2 | 12 | 2132 | 2144 | 439 |
| | 1973 | 26 | 2 | 60 | 275 | 8.3 | 9.6 | 102.6 | 2295 | 17 | 6.9 | 4.3 | 92 | 34 | .85 | 7.22 | 7.7 | 2.3 | 151 | 2941 | 3104 | 1337 |
| | 1977 | 30 | 3 | 69 | 257 | 9.8 | 11.1 | 133.9 | 3454 | 17 | 8.6 | 7.0 | 174 | 198 | .88 | .42 | 5.7 | .1 | 7 | 4274 | 4444 | 2727 |
| | 1980 | 33 | 4 | 79 | 225 | 10.9 | 12.1 | 144.8 | 4182 | 25 | 10.0 | 11.7 | 327 | 222 | .94 | 2.22 | 6.5 | .5 | 36 | 5329 | 5534 | 3827 |
| | 1984 | 37 | 5 | 86 | 187 | 12.1 | 13.2 | 146.7 | 4757 | 35 | 10.7 | 21.6 | 679 | 556 | .90 | .83 | 8.0 | .3 | 33 | 6583 | 6822 | 5096 |
| | 1989 | 42 | 6 | 99 | 185 | 13.3 | 14.6 | 174.1 | 6501 | 0 | 0 | 0 | 0 | 0 | 0 | .33 | 7.7 | .1 | 16 | 8326 | 8581 | 6808 |
| Control: | | | | | | | | | | | | | | | | | | | | | | |
| C | 1966 | 19 | 0 | 37 | 1272 | 3.5 | 5.8 | 86.3 | 1157 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 1157 | 1157 | 5 |
| | 1970 | 23 | 1 | 49 | 1310 | 4.3 | 7.4 | 134.4 | 2426 | 0 | 0 | 0 | 0 | 0 | 0 | 26.7 | 2.7 | .9 | 14 | 2426 | 2439 | 173 |
| | 1973 | 26 | 2 | 57 | 1293 | 4.9 | 8.6 | 171.5 | 3667 | 0 | 0 | 0 | 0 | 0 | 0 | 43.3 | 2.8 | 2.0 | 35 | 3667 | 3715 | 741 |
| | 1977 | 30 | 3 | 68 | 1230 | 5.6 | 9.7 | 210.6 | 5289 | 0 | 0 | 0 | 0 | 0 | 0 | 93.3 | 3.0 | 4.9 | 100 | 5289 | 5438 | 2022 |
| | 1980 | 33 | 4 | 77 | 1128 | 6.1 | 10.5 | 229.9 | 6586 | 0 | 0 | 0 | 0 | 0 | 0 | 113.3 | 3.4 | 7.1 | 160 | 6586 | 6895 | 3203 |
| | 1984 | 37 | 5 | 86 | 1010 | 6.7 | 11.2 | 248.4 | 7973 | 0 | 0 | 0 | 0 | 0 | 0 | 123.3 | 3.7 | 9.0 | 1087 | 7972 | 8505 | 4634 |
| | 1989 | 42 | 6 | 98 | 845 | 7.5 | 12.2 | 259.3 | 9503 | 0 | 0 | 0 | 0 | 0 | 0 | 163.3 | 4.7 | 19.0 | 581 | 9503 | 10616 | 6496 |

[a] Plot in treatment 1 omitted because of root rot.

[b] Estimated 450 cubic feet per acre removed in calibration is included in total yield.

Table 9b—Average per hectare stand statistics, by treatment, year, and age

| Treatment | Year | Age | Period | H40 | After thinning: Trees left | After thinning: QMD all | After thinning: QMD crop | After thinning: Basal area | After thinning: CVTS | Removed in thinning: Trees cut | Removed in thinning: QMD | Removed in thinning: Basal area | Removed in thinning: CVTS | Removed in thinning: CV6 | d/D | Mortality: Trees dead | Mortality: QMD | Mortality: Basal area | Mortality: CVTS | Cum Yield: Net CVTS | Cum Yield: Gross CVTS | Cum Yield: Net CV6 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | *m* | | *Centimeters* | | *m*[2] | *m*[3] | | *Cm* | *m*[2] | *Cubic meters* | | | | *Cm* | *m*[2] | *m*[3] | *– – Cubic meters – –* | | |
| Fixed: | | | | | | | | | | | | | | | | | | | | | | |
| 1[a] | 1966 | 19 | 0 | 12.2 | 877 | 12.2 | 14.2 | 10.2 | 44 | | | | 31.5[b] | | | | | | | 75 | 75 | 0 |
| | 1970 | 23 | 1 | 15.3 | 531 | 17.3 | 18.8 | 12.2 | 69 | 333 | 15.0 | 5.9 | 32.0 | 2.0 | 0.92 | 12 | 9.6 | 0.1 | 0.3 | 132 | 132 | 16 |
| | 1973 | 26 | 2 | 18.0 | 366 | 21.6 | 23.1 | 13.2 | 86 | 161 | 19.3 | 4.7 | 29.2 | 11.4 | .92 | 6 | 19.6 | .2 | 1.1 | 178 | 180 | 63 |
| | 1977 | 30 | 3 | 21.0 | 252 | 27.2 | 28.2 | 14.6 | 112 | 106 | 24.6 | 5.0 | 36.9 | 27.4 | .94 | 6 | 15.5 | .1 | .8 | 242 | 244 | 132 |
| | 1980 | 33 | 4 | 24.0 | 193 | 31.2 | 31.8 | 14.6 | 128 | 62 | 28.4 | 3.9 | 33.0 | 27.4 | .93 | 0 | 0 | 0 | 0 | 290 | 293 | 182 |
| | 1984 | 37 | 5 | 26.0 | 148 | 36.6 | 36.3 | 15.4 | 148 | 44 | 32.0 | 3.5 | 32.0 | 28.8 | .90 | 0 | 0 | 0 | 0 | 342 | 344 | 234 |
| | 1989 | 42 | 6 | 29.6 | 148 | 40.9 | 40.9 | 19.4 | 212 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 407 | 409 | 297 |
| 3 | 1966 | 19 | 0 | 11.4 | 860 | 12.7 | 15.0 | 10.6 | 46 | | | | 31.5 | | | | | | | 77 | 77 | 0 |
| | 1970 | 23 | 1 | 15.0 | 613 | 17.3 | 19.8 | 14.2 | 81 | 227 | 15.0 | 4.1 | 22.7 | 1.5 | .92 | 29 | 9.6 | .2 | .9 | 135 | 136 | 22 |
| | 1973 | 26 | 2 | 17.2 | 477 | 21.1 | 23.4 | 16.5 | 108 | 106 | 19.6 | 3.2 | 20.8 | 9.7 | .94 | 29 | 16.8 | .6 | 3.8 | 183 | 188 | 72 |
| | 1977 | 30 | 3 | 20.6 | 400 | 25.9 | 27.9 | 20.8 | 162 | 67 | 22.6 | 2.6 | 20.4 | 12.9 | .86 | 12 | 21.1 | .4 | 3.3 | 258 | 266 | 150 |
| | 1980 | 33 | 4 | 23.0 | 358 | 29.0 | 31.2 | 23.4 | 204 | 37 | 27.7 | 2.2 | 19.4 | 16.1 | .88 | 4 | 22.1 | .2 | 1.3 | 319 | 328 | 214 |
| | 1984 | 37 | 5 | 25.7 | 284 | 33.3 | 34.5 | 24.4 | 238 | 74 | 27.7 | 4.4 | 42.0 | 34.8 | .85 | 0 | .0 | .0 | .0 | 395 | 405 | 291 |
| | 1989 | 42 | 6 | 29.8 | 279 | 37.1 | 38.4 | 30.1 | 336 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 26.4 | .2 | 2.3 | 493 | 504 | 387 |
| 5 | 1966 | 19 | 0 | 11.7 | 857 | 13.0 | 15.5 | 11.2 | 51 | | | | 31.5 | | | | | | | 83 | 83 | 1 |
| | 1970 | 23 | 1 | 15.3 | 684 | 17.5 | 20.3 | 16.4 | 97 | 153 | 14.7 | 2.6 | 14.6 | .4 | .88 | 20 | 12.4 | .2 | 1.3 | 143 | 144 | 24 |
| | 1973 | 26 | 2 | 18.1 | 598 | 21.3 | 24.1 | 21.0 | 145 | 79 | 18.0 | 1.9 | 12.7 | 4.2 | .90 | 8 | 20.8 | .3 | 1.9 | 204 | 207 | 83 |
| | 1977 | 30 | 3 | 21.2 | 561 | 25.1 | 28.4 | 27.7 | 224 | 25 | 23.4 | 1.1 | 8.4 | 5.5 | .85 | 12 | 18.8 | .3 | 2.7 | 291 | 297 | 179 |
| | 1980 | 33 | 4 | 23.9 | 519 | 27.7 | 31.2 | 31.0 | 280 | 42 | 26.7 | 2.4 | 21.8 | 18.0 | .96 | 0 | 0 | 0 | 0 | 369 | 375 | 259 |
| | 1984 | 37 | 5 | 26.8 | 440 | 30.7 | 34.3 | 32.5 | 329 | 69 | 27.4 | 4.1 | 40.1 | 32.6 | .86 | 8 | 17.0 | .2 | 1.6 | 458 | 466 | 350 |
| | 1989 | 42 | 6 | 31.1 | 440 | 33.8 | 37.6 | 38.9 | 450 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 579 | 586 | 469 |
| 7 | 1966 | 19 | 0 | 11.7 | 889 | 12.7 | 14.5 | 11.3 | 51 | | | | 31.5 | | | | | | | 83 | 83 | 1 |
| | 1970 | 23 | 1 | 15.0 | 822 | 17.0 | 19.0 | 18.5 | 108 | 32 | 10.2 | .7 | 4.0 | .4 | .99 | 33 | 11.9 | .4 | 2.0 | 143 | 145 | 21 |
| | 1973 | 26 | 2 | 17.9 | 753 | 20.3 | 22.6 | 24.3 | 166 | 30 | 11.7 | .7 | 4.5 | 1.7 | .88 | 41 | 17.0 | .9 | 6.4 | 206 | 215 | 185 |
| | 1977 | 30 | 3 | 21.3 | 734 | 23.9 | 26.7 | 32.7 | 265 | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 18.8 | .6 | 4.3 | 305 | 317 | 188 |
| | 1980 | 33 | 4 | 23.9 | 709 | 26.2 | 29.2 | 38.0 | 348 | 17 | 10.9 | .4 | 3.6 | 1.3 | .78 | 8 | 22.4 | .3 | 2.9 | 391 | 407 | 277 |
| | 1984 | 37 | 5 | 26.8 | 642 | 28.4 | 32.0 | 41.1 | 415 | 57 | 30.7 | 3.1 | 30.4 | 23.6 | .90 | 8 | 15.7 | .2 | 1.3 | 489 | 506 | 376 |
| | 1989 | 42 | 6 | 30.7 | 630 | 31.0 | 34.8 | 47.7 | 547 | 0 | 0 | 0 | 0 | 0 | 0 | 12 | 16.3 | .2 | 2.4 | 621 | 640 | 508 |
| Increasing: | | | | | | | | | | | | | | | | | | | | | | |
| 2 | 1966 | 19 | 0 | 12.2 | 889 | 12.7 | 14.7 | 11.2 | 52 | | | | | | | | | | | 84 | 84 | 0 |
| | 1970 | 23 | 1 | 15.5 | 489 | 17.5 | 19.6 | 11.8 | 71 | 366 | 16.0 | 7.5 | 44.2 | 8.5 | 0.95 | 9.3 | 12.7 | 0.1 | 2.5 | 147 | 150 | 24 |
| | 1973 | 26 | 2 | 17.6 | 383 | 21.6 | 23.6 | 14.0 | 98 | 82 | 20.3 | 2.6 | 18.0 | 8.2 | .95 | 8.2 | 19.8 | .2 | 5.1 | 192 | 199 | 75 |
| | 1977 | 30 | 3 | 20.5 | 314 | 26.9 | 28.2 | 17.8 | 143 | 67 | 23.6 | 2.8 | 22.8 | 15.7 | .89 | 1.0 | 14.5 | 0 | .1 | 259 | 268 | 149 |
| | 1980 | 33 | 4 | 23.1 | 284 | 30.2 | 31.0 | 20.4 | 183 | 25 | 27.2 | 1.4 | 12.4 | 9.9 | .88 | 1.4 | 28.7 | .1 | 2.4 | 312 | 322 | 203 |
| | 1984 | 37 | 5 | 26.1 | 240 | 34.8 | 34.8 | 22.5 | 226 | 42 | 29.0 | 2.7 | 26.5 | 22.9 | .86 | 1.0 | 28.4 | .1 | 2.4 | 381 | 394 | 273 |
| | 1989 | 42 | 6 | 30.3 | 240 | 38.6 | 38.9 | 27.9 | 316 | 0 | 0 | 0 | 0 | 0 | .00 | 0 | 0 | 0 | 0 | 471 | 484 | 362 |

**Table 9b—Average per hectare stand statistics, by treatment, year, and age (continued)**

| | | | | | After thinning | | | | | Removed in thinning | | | | | | Mortality | | | | Cum Yield | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | Year | Age | Period | H40 | Trees left | QMD all | QMD crop | Basal area | CVTS | Trees cut | QMD | Basal area | CVTS | CV6 | d/D | Trees dead | QMD | Basal area | CVTS | Net CVTS | Gross CVTS | Net CV6 |
| | | | | $m$ | | *Centimeters* | | $m^2$ | $m^3$ | | *Cm* | $m^2$ | *Cubic meters* | | | | *Cm* | $m^2$ | $m^3$ | - - *Cubic meters* - - | | |
| Fixed: | | | | | | | | | | | | | | | | | | | | | | |
| 4 | 1966 | 19 | 0 | 12.4 | 897 | 12.7 | 15.0 | 11.4 | 54 | | | | | | | | | | | 86 | 86 | 0 |
| | 1970 | 23 | 1 | 16.1 | 600 | 17.8 | 19.8 | 14.6 | 90 | 277 | 15.5 | 5.3 | 30.9 | 3.6 | 0.91 | 5.1 | 11.9 | 0.1 | 1.3 | 152 | 154 | 27 |
| | 1973 | 26 | 2 | 18.2 | 487 | 21.8 | 23.9 | 17.8 | 125 | 79 | 18.8 | 2.2 | 14.9 | 6.9 | .88 | 12.4 | 17.8 | .3 | 6.1 | 202 | 209 | 83 |
| | 1977 | 30 | 3 | 20.9 | 445 | 26.7 | 28.4 | 24.2 | 195 | 30 | 23.9 | 1.3 | 11.0 | 8.0 | .91 | 3.1 | 14.2 | .1 | 1.2 | 283 | 292 | 173 |
| | 1980 | 33 | 4 | 23.6 | 408 | 29.7 | 31.5 | 27.7 | 253 | 32 | 24.9 | 1.6 | 13.6 | 10.2 | .85 | 1.4 | 25.4 | .1 | 1.8 | 354 | 366 | 247 |
| | 1984 | 37 | 5 | 26.6 | 378 | 32.8 | 34.8 | 31.5 | 320 | 30 | 31.2 | 2.2 | 22.5 | 19.9 | .95 | 0 | 0 | 0 | 0 | 444 | 455 | 337 |
| | 1989 | 42 | 6 | 30.4 | 375 | 36.1 | 38.1 | 37.8 | 432 | 0 | 0 | 0 | 0 | 0 | 0 | .8 | 14.5 | 0 | .6 | 557 | 569 | 449 |
| Decreasing: | | | | | | | | | | | | | | | | | | | | | | |
| 6 | 1966 | 19 | 0 | 11.2 | 889 | 12.2 | 14.5 | 10.4 | 45 | | | | | | | | | | | 76 | 76 | 0 |
| | 1970 | 23 | 1 | 14.5 | 758 | 16.8 | 19.3 | 16.5 | 92 | 91 | 15.2 | 1.6 | 8.9 | .2 | .93 | 4.2 | 10.7 | .1 | 1.7 | 132 | 134 | 17 |
| | 1973 | 26 | 2 | 17.0 | 622 | 20.3 | 22.9 | 20.0 | 130 | 106 | 18.5 | 2.3 | 18.8 | 6.0 | .93 | 9.6 | 16.0 | .2 | 3.5 | 189 | 194 | 71 |
| | 1977 | 30 | 3 | 20.5 | 501 | 24.6 | 27.4 | 23.7 | 182 | 106 | 23.4 | 2.8 | 34.7 | 23.3 | .96 | 3.1 | 16.3 | .1 | 1.8 | 276 | 283 | 164 |
| | 1980 | 33 | 4 | 22.9 | 425 | 27.7 | 30.5 | 25.5 | 222 | 74 | 24.4 | 3.7 | 29.7 | 21.6 | .89 | 1.4 | 21.3 | .1 | 1.2 | 346 | 354 | 236 |
| | 1984 | 37 | 5 | 25.5 | 316 | 31.8 | 33.8 | 25.2 | 245 | 104 | 26.7 | 5.3 | 53.3 | 43.0 | .87 | 1.0 | 28.7 | .1 | 2.6 | 422 | 433 | 313 |
| | 1989 | 42 | 6 | 29.5 | 316 | 35.3 | 38.1 | 31.1 | 345 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 522 | 533 | 412 |
| 8 | 1966 | 19 | 0 | 12.3 | 869 | 13.0 | 15.0 | 11.3 | 54 | | | | | | | | | | | 86 | 86 | 0 |
| | 1970 | 23 | 1 | 15.6 | 773 | 17.5 | 20.3 | 18.6 | 110 | 79 | 15.5 | 1.3 | 7.3 | 1.5 | .90 | 4.1 | 11.2 | 0 | .8 | 149 | 150 | 31 |
| | 1973 | 26 | 2 | 18.3 | 679 | 21.1 | 24.4 | 23.6 | 161 | 42 | 17.5 | 1.0 | 6.4 | 2.4 | .85 | 17.8 | 19.6 | .5 | 10.6 | 206 | 217 | 94 |
| | 1977 | 30 | 3 | 21.0 | 635 | 24.9 | 28.2 | 30.7 | 242 | 42 | 21.8 | 1.6 | 12.2 | 13.8 | .88 | 1.0 | 14.5 | 0 | .5 | 299 | 311 | 191 |
| | 1980 | 33 | 4 | 24.1 | 556 | 27.7 | 30.7 | 33.1 | 292 | 62 | 25.4 | 2.7 | 22.9 | 15.5 | .94 | 5.5 | 16.5 | .1 | 2.5 | 373 | 387 | 268 |
| | 1984 | 37 | 5 | 26.2 | 462 | 30.7 | 33.5 | 33.7 | 333 | 86 | 27.2 | 5.0 | 47.5 | 38.9 | .90 | 2.0 | 20.3 | .1 | 2.3 | 461 | 477 | 357 |
| | 1989 | 42 | 6 | 30.2 | 457 | 33.8 | 37.1 | 40.0 | 455 | 0 | 0 | 0 | 0 | 0 | 0 | .8 | 19.6 | 0 | 1.1 | 583 | 600 | 476 |
| Control: | | | | | | | | | | | | | | | | | | | | | | |
| C | 1966 | 19 | 0 | 11.2 | 3142 | 8.9 | 14.7 | 19.8 | 81 | 0 | 0 | 0 | 0 | 0 | 0 | | | | | 81 | 81 | 0 |
| | 1970 | 23 | 1 | 14.8 | 4298 | 10.9 | 18.8 | 30.8 | 170 | 0 | 0 | 0 | 0 | 0 | 0 | 65.9 | 6.8 | .2 | 1.0 | 170 | 171 | 12 |
| | 1973 | 26 | 2 | 17.4 | 4242 | 12.4 | 21.8 | 39.4 | 257 | 0 | 0 | 0 | 0 | 0 | 0 | 107.0 | 7.1 | .5 | 2.4 | 257 | 260 | 52 |
| | 1977 | 30 | 3 | 20.6 | 4035 | 14.2 | 24.6 | 48.3 | 370 | 0 | 0 | 0 | 0 | 0 | 0 | 230.4 | 7.6 | 1.1 | 7.0 | 370 | 381 | 141 |
| | 1980 | 33 | 4 | 23.3 | 3701 | 15.5 | 26.7 | 52.8 | 461 | 0 | 0 | 0 | 0 | 0 | 0 | 279.8 | 8.6 | 1.6 | 11.2 | 461 | 482 | 224 |
| | 1984 | 37 | 5 | 26.2 | 3314 | 17.0 | 28.4 | 57.0 | 558 | 0 | 0 | 0 | 0 | 0 | 0 | 304.6 | 9.4 | 2.1 | 76.1 | 558 | 595 | 324 |
| | 1989 | 42 | 6 | 29.9 | 2772 | 19.0 | 31.0 | 59.5 | 665 | 0 | 0 | 0 | 0 | 0 | 0 | 403.4 | 11.9 | 4.4 | 40.6 | 665 | 743 | 454 |

[a] Plot 51 in treatment 1 omitted because of root rot.

[b] Estimated 31.5 cubic meters per hectare (CVTS) removed in calibration is included in total yield.

**Table 10a—Merchantable cubic volume (CV6) per acre by treatment, plot, period, year and age**

| | | Calibration | | Period 1 | | Period 2 | | Period 3 | | Period 4 | | Period 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | Plot | After cut 1966 (19)[a] | Before cut 1970 (23) | After cut 1970 (23) | Before cut 1973 (26) | After cut 1973 (26) | Before cut 1977 (30) | After cut 1977 (30) | Before cut 1980 (33) | After cut 1980 (33) | Before cut 1984 (37) | After cut 1984 (37) | 1989 (42) |
| | | *Cubic feet* | | | | | | | | | | | |
| Fixed: | | | | | | | | | | | | | |
| 1[b] | 21 | 0 | 248 | 229 | 898 | 751 | 1725 | 1314 | 1986 | 1634 | 2424 | 1953 | 2813 |
| | 33 | 0 | 211 | 172 | 854 | 676 | 1679 | 1308 | 2036 | 1607 | 2320 | 1968 | 2910 |
| | 51 | 0 | 206 | 180 | 718 | 670 | 1429 | 1104 | 1462 | 1411 | 2021 | 1851 | 2698 |
| 3 | 31 | 0 | 204 | 204 | 908 | 796 | 1908 | 1715 | 2706 | 2369 | 3491 | 3133 | 4584 |
| | 42 | 12 | 420 | 374 | 1197 | 970 | 2115 | 2005 | 2944 | 2590 | 3624 | 3148 | 4574 |
| | 52 | 0 | 316 | 297 | 925 | 851 | 1945 | 1694 | 2493 | 2493 | 3629 | 2973 | 4243 |
| 5 | 12 | 18 | 352 | 352 | 1282 | 1232 | 2701 | 2586 | 3798 | 3453 | 4718 | 4211 | 5915 |
| | 41 | 12 | 456 | 440 | 1334 | 1230 | 2685 | 2564 | 3776 | 3446 | 4757 | 4209 | 5981 |
| | 72 | 0 | 233 | 233 | 932 | 905 | 2088 | 2088 | 3111 | 3012 | 4320 | 3976 | 5614 |
| 7 | 11 | 26 | 445 | 445 | 1520 | 1448 | 2985 | 2985 | 4331 | 4273 | 5734 | 5221 | 7093 |
| | 23 | 13 | 302 | 284 | 1091 | 1091 | 2604 | 2604 | 3806 | 3806 | 5157 | 4783 | 6690 |
| | 63 | 0 | 171 | 171 | 1016 | 1016 | 2403 | 2403 | 3577 | 3577 | 5062 | 4934 | 6821 |
| Increasing: | | | | | | | | | | | | | |
| 2 | 82 | 0 | 369 | 217 | 1027 | 883 | 1967 | 1762 | 2524 | 2333 | 3360 | 3081 | 4422 |
| | 91 | 0 | 163 | 119 | 770 | 702 | 1772 | 1443 | 2191 | 2191 | 3270 | 2889 | 4163 |
| | 101 | 0 | 518 | 349 | 1036 | 893 | 1935 | 1797 | 2593 | 2359 | 3259 | 2938 | 4127 |
| 4 | 13 | 0 | 668 | 552 | 1316 | 1209 | 2392 | 2344 | 3307 | 3260 | 4419 | 4075 | 5606 |
| | 62 | 0 | 122 | 122 | 920 | 852 | 2168 | 1979 | 3064 | 2822 | 4071 | 3900 | 5562 |
| | 111 | 13 | 372 | 335 | 1183 | 1062 | 2412 | 2304 | 3439 | 3291 | 4726 | 4387 | 5989 |
| Decreasing: | | | | | | | | | | | | | |
| 6 | 15 | 0 | 290 | 273 | 1196 | 1044 | 2291 | 1973 | 2914 | 2588 | 3619 | 3086 | 4480 |
| | 43 | 0 | 239 | 217 | 829 | 829 | 2275 | 1829 | 2827 | 2559 | 3698 | 3091 | 4539 |
| | 81 | 0 | 186 | 186 | 999 | 893 | 2168 | 1933 | 3091 | 2760 | 3899 | 3197 | 4600 |
| 8 | 14 | 0 | 615 | 551 | 1565 | 1463 | 2898 | 2769 | 3897 | 3582 | 4976 | 4370 | 6172 |
| | 53 | 0 | 319 | 319 | 1033 | 1033 | 2248 | 2075 | 3126 | 3039 | 4257 | 3738 | 5374 |
| | 73 | 18 | 382 | 382 | 1350 | 1350 | 2870 | 2845 | 3967 | 3703 | 4895 | 4351 | 6050 |
| Unthinned: | | | | | | | | | | | | | |
| C | 22 | 0 | 153 | 153 | 734 | 734 | 2241 | 2241 | 3564 | 3564 | 4955 | 4955 | 6839 |
| | 25 | 0 | 246 | 246 | 807 | 807 | 2038 | 2038 | 3132 | 3132 | 4655 | 4655 | 6657 |
| | 71 | 16 | 120 | 120 | 683 | 683 | 1787 | 1787 | 2913 | 2913 | 4293 | 4293 | 5992 |

[a] Stand age in parentheses.

[b] Plot 51 abandoned 1989 because of severe root rot.

**Table 10b—Merchantable cubic volume (CV6) per hectare by treatment, plot, period, year and age**

| | | Calibration | | Period 1 | | Period 2 | | Period 3 | | Period 4 | | Period 5 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Treatment | Plot | After cut 1966 (19)[a] | Before cut 1970 (23) | After cut 1970 (23) | Before cut 1973 (26) | After cut 1973 (26) | Before cut 1977 (30) | After cut 1977 (30) | Before cut 1980 (33) | After cut 1980 (33) | Before cut 1984 (37) | After cut 1984 (37) | 1989 (42) |
| | | *Cubic feet* | | | | | | | | | | | |
| Fixed: | | | | | | | | | | | | | |
| 1[b] | 21 | 0 | 17 | 16 | 63 | 53 | 121 | 92 | 139 | 114 | 170 | 137 | 197 |
| | 33 | 0 | 15 | 12 | 60 | 47 | 117 | 91 | 142 | 112 | 162 | 138 | 204 |
| | 51 | 0 | 14 | 13 | 50 | 47 | 100 | 77 | 102 | 99 | 141 | 130 | 189 |
| 3 | 31 | 0 | 14 | 14 | 64 | 56 | 134 | 120 | 189 | 166 | 244 | 219 | 321 |
| | 42 | 1 | 29 | 26 | 84 | 68 | 148 | 140 | 206 | 181 | 254 | 220 | 320 |
| | 52 | 0 | 22 | 21 | 65 | 60 | 136 | 119 | 174 | 174 | 254 | 208 | 297 |
| 5 | 12 | 1 | 25 | 25 | 90 | 86 | 189 | 181 | 266 | 242 | 330 | 295 | 414 |
| | 41 | 1 | 32 | 31 | 93 | 86 | 188 | 179 | 264 | 241 | 333 | 295 | 419 |
| | 72 | 0 | 16 | 16 | 65 | 63 | 146 | 146 | 218 | 211 | 302 | 278 | 393 |
| 7 | 11 | 2 | 31 | 31 | 106 | 101 | 209 | 209 | 303 | 299 | 401 | 365 | 496 |
| | 23 | 1 | 21 | 20 | 76 | 76 | 182 | 182 | 266 | 266 | 361 | 335 | 468 |
| | 63 | 0 | 12 | 12 | 71 | 71 | 168 | 168 | 250 | 250 | 354 | 345 | 477 |
| Increasing: | | | | | | | | | | | | | |
| 2 | 82 | 0 | 26 | 15 | 72 | 62 | 138 | 123 | 177 | 163 | 235 | 216 | 309 |
| | 91 | 0 | 11 | 8 | 54 | 49 | 124 | 101 | 153 | 153 | 229 | 202 | 291 |
| | 101 | 0 | 36 | 24 | 73 | 63 | 135 | 126 | 181 | 165 | 228 | 206 | 289 |
| 4 | 13 | 0 | 47 | 39 | 92 | 85 | 167 | 164 | 231 | 228 | 309 | 285 | 392 |
| | 62 | 0 | 9 | 9 | 64 | 60 | 152 | 138 | 214 | 197 | 285 | 273 | 389 |
| | 111 | 1 | 26 | 23 | 83 | 74 | 169 | 161 | 241 | 230 | 331 | 307 | 419 |
| Decreasing: | | | | | | | | | | | | | |
| 6 | 15 | 0 | 20 | 19 | 84 | 73 | 160 | 138 | 204 | 181 | 253 | 216 | 313 |
| | 43 | 0 | 17 | 15 | 58 | 58 | 159 | 128 | 198 | 179 | 259 | 216 | 318 |
| | 81 | 0 | 13 | 13 | 70 | 62 | 152 | 135 | 216 | 193 | 273 | 224 | 322 |
| 8 | 14 | 0 | 43 | 39 | 109 | 102 | 203 | 194 | 273 | 251 | 348 | 306 | 432 |
| | 53 | 0 | 22 | 22 | 72 | 72 | 157 | 145 | 219 | 213 | 298 | 262 | 376 |
| | 73 | 1 | 27 | 27 | 94 | 94 | 201 | 199 | 278 | 259 | 343 | 304 | 423 |
| Unthinned: | | | | | | | | | | | | | |
| C | 22 | 0 | 11 | 11 | 51 | 51 | 157 | 157 | 249 | 249 | 347 | 347 | 479 |
| | 25 | 0 | 17 | 17 | 56 | 56 | 143 | 143 | 219 | 219 | 326 | 326 | 466 |
| | 71 | 1 | 8 | 8 | 48 | 48 | 125 | 125 | 204 | 204 | 300 | 300 | 419 |

[a] Stand age in parentheses.

[b] Plot 51 abandoned 1989 because of severe root rot.

**Table 11a—Periodic annual increment in net basal area per acre, by treatment and period**

| Treatment | Calibration; midperiod age 21.0 | Period 1; midperiod age 24.5 | Period 2; midperiod age 28.0 | Period 3; midperiod age 31.5 | Period 4; midperiod age 35.0 | Period 5; midperiod age 39.5 |
|---|---|---|---|---|---|---|
| | | | *Square feet* | | | |
| Fixed: | | | | | | |
| 1[a] | 8.6 | 8.3 | 6.9 | 5.7 | 4.6 | 3.5 |
| 3 | 8.4 | 8.0 | 7.5 | 6.9 | 6.0 | 4.9 |
| 5 | 8.5 | 9.5 | 8.5 | 8.2 | 6.2 | 5.6 |
| 7 | 8.6 | 9.4 | 9.2 | 8.2 | 6.8 | 5.7 |
| Increasing: | | | | | | |
| 2 | 8.9 | 6.9 | 7.3 | 5.9 | 5.2 | 4.7 |
| 4 | 9.2 | 7.9 | 8.4 | 7.4 | 6.5 | 5.5 |
| Decreasing: | | | | | | |
| 6 | 8.4 | 9.4 | 9.0 | 7.6 | 5.9 | 5.1 |
| 8 | 9.4 | 8.7 | 9.6 | 7.5 | 5.9 | 5.5 |
| Unthinned: | | | | | | |
| C | 10.7 | 11.2 | 9.2 | 7.4 | 5.2 | 3.3 |

[a] Plot 51 omitted from treatment 1 means because of root rot.

**Table 11b—Periodic annual increment in net basal area per hectare, by treatment and period**

| Treatment | Calibration; midperiod age 21.0 | Period 1; midperiod age 24.5 | Period 2; midperiod age 28.0 | Period 3; midperiod age 31.5 | Period 4; midperiod age 35.0 | Period 5; midperiod age 39.5 |
|---|---|---|---|---|---|---|
| | | | *Square meters* | | | |
| Fixed: | | | | | | |
| 1[a] | 1.97 | 1.90 | 1.59 | 1.31 | 1.05 | 0.80 |
| 3 | 1.93 | 1.85 | 1.73 | 1.59 | 1.37 | 1.13 |
| 5 | 1.95 | 2.17 | 1.95 | 1.89 | 1.41 | 1.28 |
| 7 | 1.98 | 2.16 | 2.10 | 1.89 | 1.56 | 1.32 |
| Increasing: | | | | | | |
| 2 | 2.05 | 1.58 | 1.67 | 1.34 | 1.20 | 1.09 |
| 4 | 2.11 | 1.80 | 1.92 | 1.70 | 1.49 | 1.27 |
| Decreasing: | | | | | | |
| 6 | 1.93 | 2.16 | 2.06 | 1.73 | 1.36 | 1.18 |
| 8 | 2.15 | 1.99 | 2.20 | 1.73 | 1.36 | 1.26 |
| Unthinned: | | | | | | |
| C | 2.46 | 2.58 | 2.10 | 1.70 | 1.20 | 0.75 |

[a] Plot 51 omitted from treatment 1 means because of root rot.

**Table 12a—Periodic annual net increment in quadratic mean diameter of all trees and of survivors (control only, in parentheses), by treatment and period**

| Treatment | Calibration; midperiod age 21.0 | Period 1; midperiod age 24.5 | Period 2; midperiod age 28.0 | Period 3; midperiod age 31.5 | Period 4; midperiod age 35.0 | Period 5; midperiod age 39.5 |
|---|---|---|---|---|---|---|
| | | | *Inches* | | | |
| Fixed: | | | | | | |
| 1[a] | 0.41 | 0.49 | 0.48 | 0.45 | 0.42 | 0.36 |
| 3 | .41 | .47 | .43 | .39 | .32 | .31 |
| 5 | .40 | .43 | .38 | .32 | .26 | .23 |
| 7 | .41 | .43 | .35 | .28 | .22 | .20 |
| Increasing: | | | | | | |
| 2 | .42 | .49 | .47 | .41 | .36 | .31 |
| 4 | .42 | .48 | .45 | .37 | .30 | .26 |
| Decreasing: | | | | | | |
| 6 | .42 | .44 | .40 | .35 | .29 | .28 |
| 8 | .43 | .44 | .36 | .31 | .24 | .23 |
| Unthinned: | | | | | | |
| C | .21 | .20 | .17 | .17 | .15 | .16 |
| | (.21)[b] | (.20) | (.15) | (.12) | (.10) | (.09) |

[a] Plot 51 omitted from treatment 1 means because of root rot.
[b] Survivor growth.

**Table 12b—Periodic annual net increment in quadratic mean diameter of all trees and of survivors (control only, in parentheses), by treatment and period**

| Treatment | Calibration; midperiod age 21.0 | Period 1; midperiod age 24.5 | Period 2; midperiod age 28.0 | Period 3; midperiod age 31.5 | Period 4; midperiod age 35.0 | Period 5; midperiod age 39.5 |
|---|---|---|---|---|---|---|
| | | | *Centimeters* | | | |
| Fixed: | | | | | | |
| 1[a] | 1.04 | 1.24 | 1.22 | 1.14 | 1.07 | 0.91 |
| 3 | 1.04 | 1.19 | 1.09 | .99 | .82 | .79 |
| 5 | 1.02 | 1.09 | .96 | .81 | .66 | .58 |
| 7 | 1.04 | 1.09 | .89 | .71 | .56 | .51 |
| Increasing: | | | | | | |
| 2 | 1.07 | 1.24 | 1.19 | 1.04 | .91 | .79 |
| 4 | 1.07 | 1.22 | 1.14 | .94 | .76 | .66 |
| Decreasing: | | | | | | |
| 6 | 1.07 | 1.12 | 1.02 | .89 | .74 | .71 |
| 8 | 1.09 | 1.12 | .91 | .79 | .61 | .58 |
| Unthinned: | | | | | | |
| C | .53 | .51 | .43 | .43 | .38 | .41 |
| | (.53)[b] | (.51) | (.38) | (.30) | (.25) | (.23) |

[a] Plot 51 omitted from treatment 1 means because of root rot.
[b] Survivor growth.

**Table 13a—Periodic annual increment in net total cubic volume (CVTS) and merchantable volume (CV6) per acre, by treatment and period**

| Treatment | | Calibration; midperiod age 21.0 | Period 1; midperiod age 24.5 | Period 2; midperiod age 28.0 | Period 3; midperiod age 31.5 | Period 4; midperiod age 35.0 | Period 5; midperiod age 39.5 |
|---|---|---|---|---|---|---|---|
| | | | | *Cubic feet* | | | |
| Fixed: | | | | | | | |
| 1[a] | CVTS | 203 | 220 | 227 | 231 | 186 | 184 |
| | CV6 | 57 | 225 | 247 | 234 | 188 | 180 |
| 3 | CVTS | 207 | 230 | 267 | 289 | 274 | 278 |
| | CV6 | 77 | 239 | 279 | 303 | 274 | 276 |
| 5 | CVTS | 217 | 288 | 312 | 372 | 318 | 346 |
| | CV6 | 84 | 280 | 342 | 383 | 324 | 341 |
| 7 | CVTS | 217 | 300 | 351 | 412 | 350 | 377 |
| | CV6 | 73 | 303 | 370 | 414 | 358 | 378 |
| Increasing: | | | | | | | |
| 2 | CVTS | 226 | 212 | 242 | 249 | 248 | 257 |
| | CV6 | 88 | 239 | 266 | 256 | 251 | 254 |
| 4 | CVTS | 237 | 237 | 289 | 340 | 319 | 322 |
| | CV6 | 96 | 268 | 321 | 354 | 320 | 320 |
| Decreasing: | | | | | | | |
| 6 | CVTS | 201 | 268 | 313 | 330 | 274 | 285 |
| | CV6 | 60 | 261 | 331 | 344 | 276 | 283 |
| 8 | CVTS | 229 | 270 | 333 | 352 | 314 | 349 |
| | CV6 | 108 | 300 | 347 | 367 | 317 | 342 |
| Unthinned: | | | | | | | |
| C | CVTS | 317 | 414 | 406 | 432 | 347 | 332 |
| | CV6 | 42 | 419 | 320 | 394 | 358 | 372 |

[a] Plot 51 omitted from treatment 1 means because of root rot.

**Table 13b—Periodic annual increment in net total cubic volume (CVTS) and merchantable volume (CV6) per hectare, by treatment and period**

| Treatment | | Calibration; midperiod age 21.0 | Period 1; midperiod age 24.5 | Period 2; midperiod age 28.0 | Period 3; midperiod age 31.5 | Period 4; midperiod age 35.0 | Period 5; midperiod age 39.5 |
|---|---|---|---|---|---|---|---|
| | | *Cubic meters* | | | | | |
| Fixed: | | | | | | | |
| 1[a] | CVTS | 14.2 | 15.4 | 15.9 | 16.2 | 13.0 | 12.9 |
| | CV6 | 4.0 | 15.7 | 17.3 | 16.4 | 13.2 | 12.6 |
| 3 | CVTS | 14.5 | 16.1 | 18.7 | 20.2 | 19.2 | 19.4 |
| | CV6 | 5.4 | 16.7 | 19.5 | 21.2 | 19.2 | 19.3 |
| 5 | CVTS | 15.2 | 20.2 | 21.8 | 26.0 | 22.2 | 24.2 |
| | CV6 | 5.9 | 19.6 | 23.9 | 26.8 | 22.7 | 23.9 |
| | CVTS | 15.2 | 21.0 | 24.6 | 28.8 | 24.5 | 26.4 |
| | CV6 | 5.1 | 21.2 | 25.9 | 29.0 | 25.0 | 26.4 |
| Increasing: | | | | | | | |
| 2 | CVTS | 15.8 | 14.8 | 16.9 | 17.4 | 17.4 | 18.0 |
| | CV6 | 6.2 | 16.7 | 18.6 | 17.9 | 17.6 | 17.8 |
| 4 | CVTS | 16.6 | 16.6 | 20.2 | 23.8 | 22.3 | 22.5 |
| | CV6 | 6.7 | 18.8 | 22.5 | 24.8 | 22.4 | 22.4 |
| Decreasing: | | | | | | | |
| 6 | CVTS | 14.1 | 18.8 | 21.9 | 23.1 | 19.2 | 19.9 |
| | CV6 | 4.2 | 18.3 | 23.2 | 24.1 | 19.3 | 19.8 |
| 8 | CVTS | 16.0 | 18.9 | 23.3 | 24.6 | 22.0 | 24.4 |
| | CV6 | 7.6 | 21.0 | 24.3 | 25.7 | 22.2 | 23.9 |
| Unthinned: | | | | | | | |
| C | CVTS | 22.2 | 29.0 | 28.4 | 30.2 | 24.3 | 23.2 |
| | CV6 | 2.9 | 29.3 | 22.4 | 27.6 | 25.0 | 26.0 |

[a] Plot 51 omitted from treatment 1 means because of root rot.

**Table 14a—Periodic annual mortality in number of trees and in basal area, per acre, by treatment and period**

| Treatment | Calibration; midperiod age 21.0 | Period 1; midperiod age 24.5 | Period 2; midperiod age 28.0 | Period 3; midperiod age 31.5 | Period 4; midperiod age 35.0 | Period 5; midperiod age 39.5 |
|---|---|---|---|---|---|---|
| | | | *Number per acre* | | | |
| Fixed: | | | | | | |
| 1[a] | 1.25 | 0.84 | 0.63 | 0 | 0 | 0* |
| 3 | 2.08 | 3.89 | 1.25 | .56 | 0 | .33 |
| 5 | 2.08 | .11 | 1.25 | 0 | .83 | 0 |
| 7 | 3.33 | 5.56 | 2.08 | 1.11 | .83 | 1.00 |
| Increasing: | | | | | | |
| 2 | 3.75 | 3.33 | .42 | .56 | .42 | 0 |
| 4 | 2.08 | 5.00 | 1.25 | .56 | 0 | .33 |
| Decreasing: | | | | | | |
| 6 | 4.17 | 3.89 | 1.25 | .56 | .42 | 0 |
| 8 | 1.67 | 7.22 | .42 | 2.22 | .83 | .33 |
| Control: | | | | | | |
| C | 6.67 | 14.44 | 23.33 | 37.78 | 24.17 | 32.67 |
| | | | *Basal area, square feet per acre* | | | |
| Fixed: | | | | | | |
| 1[a] | .09 | .25 | .13 | 0 | 0 | 0 |
| 3 | .22 | .92 | .47 | .23 | 0 | .20 |
| 5 | .27 | .41 | .38 | 0 | .21 | 0 |
| 7 | .18 | .30 | .54 | .11 | .10 | .09 |
| Increasing: | | | | | | |
| 2 | .51 | 1.07 | .07 | .39 | .28 | 0 |
| 4 | .27 | 1.30 | .20 | .30 | 0 | .06 |
| Decreasing: | | | | | | |
| 6 | .41 | .87 | .29 | .21 | .29 | 0 |
| 8 | .18 | 2.34 | .07 | .51 | .29 | .11 |
| Control: | | | | | | |
| C | .23 | .67 | 1.22 | 2.38 | 1.75 | 3.81 |

[a] Plot 51 in treatment 1 excluded because of root rot.

**Table 14b—Periodic annual mortality in number of trees and in basal area, per hectare, by treatment and period**

| Treatment | Calibration; midperiod age 21.0 | Period 1; midperiod age 24.5 | Period 2; midperiod age 28.0 | Period 3; midperiod age 31.5 | Period 4; midperiod age 35.0 | Period 5; midperiod age 39.5 |
|---|---|---|---|---|---|---|
| | | | *Number per hectare* | | | |
| Fixed: | | | | | | |
| 1[a] | 3.10 | 2.10 | 1.60 | 0 | 0 | 0 |
| 3 | 5.10 | 9.60 | 3.10 | 1.40 | .00 | .80 |
| 5 | 5.10 | .30 | 3.10 | 0 | 2.00 | 0 |
| 7 | 8.20 | 13.70 | 5.10 | 2.70 | 2.00 | 2.50 |
| Increasing | | | | | | |
| 2 | 9.30 | 8.20 | 1.00 | 1.40 | 1.00 | 0 |
| 4 | 5.10 | 12.40 | 3.10 | 1.40 | 0 | .80 |
| Decreasing | | | | | | |
| 6 | 10.30 | 9.60 | 3.10 | 1.40 | 1.00 | 0 |
| 8 | 4.10 | 17.80 | 1.00 | 5.50 | 2.00 | .80 |
| Control | | | | | | |
| C | 16.50 | 35.70 | 57.60 | 93.30 | 59.70 | 80.70 |
| | | | *Basal area, square meters* | | | |
| Fixed: | | | | | | |
| 1[a] | .02 | .06 | .03 | 0 | 0 | 0 |
| 3 | .05 | .21 | .11 | .05 | 0 | .05 |
| 5 | .06 | .09 | .09 | .00 | .05 | 0 |
| 7 | .04 | .07 | .12 | .02 | .02 | .02 |
| Increasing | | | | | | |
| 2 | .12 | .25 | .02 | .09 | .06 | 0 |
| 4 | .06 | .30 | .06 | .07 | 0 | .01 |
| Decreasing | | | | | | |
| 6 | .09 | .20 | .07 | .05 | .07 | 0 |
| 8 | .04 | .54 | .02 | .12 | .07 | .02 |
| Control | | | | | | |
| C | .05 | .15 | .28 | .55 | .40 | .87 |

[a] Plot 51 in treatment 1 excluded because of root rot.

**Table 15a—Periodic annual mortality in total cubic volume (CVTS) per acre, by treatment and period**

| Treatment | Calibration; midperiod age 21.0 | Period 1; midperiod age 24.5 | Period 2; midperiod age 28.0 | Period 3; midperiod age 31.5 | Period 4; midperiod age 35.0 | Period 5; midperiod age 39.5 |
|---|---|---|---|---|---|---|
| | | | *Cubic feet per acre* | | | |
| Fixed: | | | | | | |
| 1[a] | 1.1 | 5.4 | 2.8 | 0 | 0 | 0 |
| 3 | 3.3 | 18.3 | 11.7 | 6.1 | .0 | 6.7 |
| 5 | 4.5 | 9.0 | 9.5 | 0 | 5.8 | 0 |
| 7 | 7.2 | 30.6 | 15.4 | 13.8 | 4.8 | 6.7 |
| Increasing | | | | | | |
| 2 | 9.1 | 24.3 | 1.7 | 11.3 | 8.8 | 0 |
| 4 | 4.5 | 29.0 | 4.2 | 8.5 | 0 | 1.6 |
| Decreasing | | | | | | |
| 6 | 6.3 | 16.6 | 6.5 | 5.6 | 9.3 | 0 |
| 8 | 3.0 | 50.4 | 1.6 | 12.0 | 8.2 | 3.2 |
| Control | | | | | | |
| C | 3.4 | 11.6 | 25.0 | 53.2 | 56.0 | 116.1 |

[a] Plot 51 in treatment 1 excluded because of root rot. CV6 mortality has been negligible.

**Table 15b—Periodic annual mortality in total cubic volume (CVTS) per hectare, by treatment and period**

| Treatment | Calibration; midperiod age 21.0 | Period 1; midperiod age 24.5 | Period 2; midperiod age 28.0 | Period 3; midperiod age 31.5 | Period 4; midperiod age 35.0 | Period 5; midperiod age 39.5 |
|---|---|---|---|---|---|---|
| | | | *Cubic meters* | | | |
| Fixed: | | | | | | |
| 1[a] | 0.07 | 0.38 | 0.20 | 0 | 0 | 0 |
| 3 | .23 | 1.28 | .82 | .42 | 0 | .47 |
| 5 | .31 | .63 | .66 | 0 | .40 | 0 |
| 7 | .50 | 2.14 | 1.08 | .96 | .34 | .47 |
| Increasing: | | | | | | |
| 2 | .64 | 1.70 | .12 | .79 | .62 | 0 |
| 4 | .31 | 2.03 | .29 | .59 | 0 | .11 |
| Decreasing: | | | | | | |
| 6 | .44 | 1.16 | .45 | .39 | .65 | 0 |
| 8 | .21 | 3.53 | .11 | .84 | .57 | .22 |
| Control: | | | | | | |
| C | .24 | .81 | 1.75 | 3.72 | 3.92 | 8.12 |

[a] Plot 51 in treatment 1 excluded because of root rot. CV6 mortality has been negligible.

**Table 16—Net basal area (BA) growth percent, net cubic volume (CVTS) growth percent, and net merchantable volume (CV6) growth percent (based on midperiod values), by treatment and period**

| | | Period | | | | | |
|---|---|---|---|---|---|---|---|
| Treatment | Unit | Calibration 1966-70 age 21.0 | TP-1 1970-73 age 24.5 | TP-2 1973-77 age 28.0 | TP-3 1977-80 age 31.5 | TP-4 1980-84 age 35.0 | TP-5 1984-89 age 39.5 |
| | | *Percent* | | | | | |
| Fixed: | | | | | | | |
| 1[a] | BA | 13.9 | 12.6 | 9.7 | 7.9 | 6.3 | 4.6 |
| | CVTS | 19.6 | 16.8 | 13.5 | 11.8 | 8.5 | 7.1 |
| | CV6 | 50.0 | 41.9 | 20.5 | 14.1 | 9.4 | 7.3 |
| 3 | BA | 13.3 | 10.9 | 8.7 | 6.8 | 5.2 | 4.1 |
| | CVTS | 19.4 | 15.3 | 12.8 | 10.4 | 7.9 | 6.8 |
| | CV6 | 49.1 | 37.1 | 19.6 | 13.4 | 9.1 | 7.3 |
| 5 | BA | 13.0 | 11.1 | 7.8 | 6.2 | 4.2 | 3.6 |
| | CVTS | 18.5 | 15.8 | 11.5 | 9.9 | 6.9 | 6.2 |
| | CV6 | 47.6 | 37.2 | 19.0 | 12.8 | 8.2 | 6.8 |
| 7 | BA | 13.0 | 9.9 | 7.4 | 5.3 | 3.8 | 3.0 |
| | CVTS | 18.6 | 15.0 | 11.4 | 9.3 | 6.2 | 5.5 |
| | CV6 | 46.8 | 41.0 | 19.4 | 12.6 | 7.8 | 6.4 |
| Increasing: | | | | | | | |
| 2 | BA | 13.4 | 11.0 | 9.7 | 6.8 | 5.2 | 4.3 |
| | CVTS | 18.9 | 15.8 | 12.9 | 10.3 | 8.0 | 6.7 |
| | CV6 | 50.0 | 41.8 | 19.7 | 12.6 | 9.0 | 7.0 |
| 4 | BA | 13.5 | 10.4 | 8.9 | 6.4 | 4.8 | 3.7 |
| | CVTS | 19.0 | 14.5 | 12.2 | 10.1 | 7.5 | 6.0 |
| | CV6 | 48.9 | 38.5 | 19.2 | 13.0 | 8.5 | 6.5 |
| Decreasing: | | | | | | | |
| 6 | BA | 13.5 | 10.9 | 8.5 | 6.6 | 4.8 | 4.2 |
| | CVTS | 19.3 | 15.5 | 12.6 | 10.6 | 7.4 | 6.8 |
| | CV6 | 49.1 | 40.9 | 19.4 | 13.6 | 8.4 | 7.3 |
| 8 | BA | 13.8 | 9.2 | 7.9 | 5.2 | 3.8 | 3.4 |
| | CVTS | 18.6 | 13.5 | 11.2 | 8.6 | 6.5 | 6.2 |
| | CV6 | 48.5 | 34.8 | 17.7 | 11.9 | 7.8 | 6.9 |
| Unthinned: | | | | | | | |
| C | BA | 11.0 | 8.1 | 5.1 | 2.9 | 1.9 | .9 |
| | CVTS | 17.8 | 13.6 | 9.0 | 7.3 | 4.8 | 3.5 |
| | CV6 | 46.1 | 42.0 | 23.1 | 15.1 | 9.2 | 6.7 |

[a] Treatment 1 mean omits plot 51, because of root rot.

**Table 17a—Net mean annual increment in total cubic feet (CVTS) and merchantable cubic feet (CV6) per acre, by treatment, year, and age**

| Treatment | Unit | 1966 (19)[a] | 1970 (23) | 1973 (26) | 1977 (30) | 1980 (33) | 1984 (37) | 1989 (42) |
|---|---|---|---|---|---|---|---|---|
| | | Cubic feet per acre per year[b] | | | | | | |
| Fixed: | | | | | | | | |
| 1[c] | CVTS | 57 | 82 | 98 | 115 | 126 | 132 | 138 |
| | CV6 | 0 | 10 | 35 | 63 | 79 | 90 | 101 |
| 3 | CVTS | 58 | 84 | 101 | 123 | 138 | 153 | 168 |
| | CV6 | 0 | 14 | 40 | 72 | 93 | 112 | 132 |
| 5 | CVTS | 62 | 89 | 112 | 139 | 160 | 177 | 197 |
| | CV6 | 0 | 15 | 46 | 85 | 112 | 135 | 160 |
| 7 | CVTS | 62 | 89 | 114 | 145 | 169 | 189 | 211 |
| | CV6 | 9 | 20 | 52 | 95 | 124 | 149 | 176 |
| Increasing: | | | | | | | | |
| 2 | CVTS | 63 | 91 | 105 | 124 | 135 | 147 | 160 |
| | CV6 | 0 | 15 | 41 | 71 | 88 | 106 | 123 |
| 4 | CVTS | 65 | 95 | 111 | 135 | 154 | 171 | 189 |
| | CV6 | 0 | 17 | 46 | 82 | 107 | 130 | 153 |
| Decreasing: | | | | | | | | |
| 6 | CVTS | 57 | 82 | 104 | 132 | 150 | 163 | 178 |
| | CV6 | 0 | 10 | 39 | 78 | 102 | 121 | 140 |
| 8 | CVTS | 64 | 93 | 113 | 142 | 161 | 178 | 198 |
| | CV6 | 0 | 19 | 51 | 91 | 116 | 138 | 162 |
| Control: | | | | | | | | |
| C | CVTS | 61 | 105 | 141 | 176 | 200 | 215 | 226 |
| | CV6 | 0 | 8 | 28 | 67 | 97 | 125 | 155 |

[a] Stand age in parentheses.

[b] Estimated cut of 450 cubic feet per acre has been included in totals for CVTS.

[c] Plot 51 in treatment 1 excluded because of root rot.

**Table 17b—Net mean annual increment in total cubic volume (CVTS) and merchantable cubic volume (CV6) per hectare, by treatment, year, and age**

| Treatment | Unit | 1966 (19)[a] | 1970 (23) | 1973 (26) | 1977 (30) | 1980 (33) | 1984 (37) | 1989 (42) |
|---|---|---|---|---|---|---|---|---|
| | | Cubic meters[b] | | | | | | |
| Fixed: | | | | | | | | |
| 1[c] | CVTS | 4.0 | 5.7 | 6.9 | 8.0 | 8.8 | 9.2 | 9.7 |
| | CV6 | 0 | .7 | 2.4 | 4.4 | 5.5 | 6.3 | 7.1 |
| 3 | CVTS | 4.1 | 5.9 | 7.1 | 8.6 | 9.7 | 10.7 | 11.8 |
| | CV6 | 0 | 1.0 | 2.8 | 5.0 | 6.5 | 7.8 | 9.2 |
| 5 | CVTS | 4.3 | 6.2 | 7.8 | 9.7 | 11.2 | 12.4 | 13.8 |
| | CV6 | 0 | 1.0 | 3.2 | 5.9 | 7.8 | 9.4 | 11.2 |
| 7 | CVTS | 4.3 | 6.2 | 8.0 | 10.1 | 11.8 | 13.2 | 14.8 |
| | CV6 | .6 | 1.4 | 3.6 | 6.6 | 8.7 | 10.4 | 12.3 |
| Increasing: | | | | | | | | |
| 2 | CVTS | 4.4 | 6.4 | 7.3 | 8.7 | 9.4 | 10.3 | 11.2 |
| | CV6 | 0 | 1.0 | 2.9 | 5.0 | 6.2 | 7.4 | 8.6 |
| 4 | CVTS | 4.5 | 6.6 | 7.8 | 9.4 | 10.8 | 12.0 | 13.2 |
| | CV6 | 0 | 1.2 | 3.2 | 5.7 | 7.5 | 9.1 | 10.7 |
| Decreasing: | | | | | | | | |
| 6 | CVTS | 4.0 | 5.7 | 7.3 | 9.2 | 10.5 | 11.4 | 12.5 |
| | CV6 | 0 | .7 | 2.7 | 5.5 | 7.1 | 8.5 | 9.8 |
| 8 | CVTS | 4.5 | 6.5 | 7.9 | 9.9 | 11.3 | 12.5 | 13.8 |
| | CV6 | 0 | 1.3 | 3.6 | 6.4 | 8.1 | 9.7 | 11.3 |
| Control: | | | | | | | | |
| C | CVTS | 4.3 | 7.3 | 9.9 | 12.3 | 14.0 | 15.0 | 15.8 |
| | CV6 | 0 | 8.0 | 2.0 | 4.7 | 6.8 | 8.7 | 10.8 |

[a] Stand age in parentheses
[b] Estimated calibration cut of 31.5 cubic meters per hectare has been included in totals for CVTS.
[c] Plot 51 in treatment 1 excluded because of root rot.

## Appendix 3: The Nine Study Areas

| Study Area | Cooperator |
|---|---|
| Skykomish<br>Clemons | Western Forestry Research Department<br>Weyerhaeuser Company<br>Tacoma, WA |
| Hoskins | College of Forestry<br>Oregon State University<br>Corvallis, OR |
| Rocky Brook<br>Stampede Creek<br>Iron Creek | USDA Forest Service<br>Pacific Northwest Research Station and<br>Pacific Northwest Region<br>Portland, OR |
| Francis | State of Washington<br>Department of Natural Resources<br>Olympia, WA |
| Sayward Forest<br>Shawnigan Lake | Canadian Forest Service<br>Pacific and Yukon Region<br>Pacific Forest Research Centre<br>Victoria, BC |

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**Curtis, Robert O.; Clendenen, Gary W. 1994.** Levels-of-growing-stock cooperative study in Douglas-fir: report no. 12—the Iron Creek study: 1966-89. Res. Pap. PNW-RP-475. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 67 p.

Results of the Iron Creek installation of the levels-of-growing-stock study in Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) are summarized. To age 42 (planned completion of the experiment) volume growth in this site II Douglas-fir plantation has been strongly related to level of growing stock, partially offsetting the decrease in volume growth percent expected with increasing growing stock. Basal area growth-growing stock relations were much weaker than those for volume. Marked differences in tree size distributions have resulted from thinning. Periodic annual volume increments are two to three times greater than mean annual increments at age 42; this stand is far from culmination. Results in general are similar to those reported for other installations in the series on medium to good sites.

Keywords: Thinning, growing stock, growth and yield, stand density, Douglas-fir, *Pseudotsuga menziesii*, series—Douglas-fir LOGS.



Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, Oregon 97208-3890

U.S. Department of Agriculture
Pacific Northwest Research Station
333 S.W. First Avenue
P.O. Box 3890
Portland, OR 97208